EFFECTS OF RESERVOIR SEDIMENTATION AND THE ECONOMICS OF WATERSHED MANAGEMENT: CASE STUDY OF AGUACATE DAM, DOMINICAN REPUBLIC

By

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Chair: Dr. Gustavo Antonini
Cochair: Dr. Peter Waylen
Major Department: Geography

Sedimentation reduction due to watershed management programs and the economic effects are determined for Aguacate hydroelectricity dam in the Dominican Republic. The Aguacate basin is located in the middle lower part of Nizao watershed. It occupies 231.13 km^2 area. It comprises two sub-basins, Mahomita and Jiguey. The study was performed by using the SWRRB (Simulator for Water Resources in Rural Basins) hydrologic simulation model. This model estimates changes in sedimentation rates under different land use scenarios. The geographic information system was used to assemble the spatial data needed to determine the sediment yield using the hydrological model. To integrate these predictions of physical quantities of erosion and sediment yields into an economic framework, a benefit-cost analysis is included. This case study evaluates two scenarios: first, the current land use ("without" project) and second, the proposed land uses ("with" project). More than 62 percent of the lands in the basin are not being used according to their capability, only 13.3 percent are covered in natural forest, while one third are in agricultural crops. Results of this study indicate that appropriate land use changes are significant in controlling upstream erosion and therefore reservoir sedimentation. It is observed that micro-basins with the largest areas of annual crops present higher sediment yields than those areas with lowest areas of annual crops. The predicted sediment yields, using the proposed land use changes for those areas in land use conflicts, showed that sediment delivered to the Aguacate reservoir decreases 67.7 percent from 387,713 m^3/yr "without" project to 125,399 m^3/yr "with" project. The expected lifespan of the reservoir is extended by more than 50 percent when project management is implemented. Model results are compared with observed-yield data from bathymetric studies of the region. The economic analysis results suggest that a "with" project management scenario is an economically attractive control strategy for reducing sediment damages. The net present values (NPV) and the benefit-cost ratio, given the discount rate equal to or less than 16 percent show that the watershed management project represents an economically efficient use of resources.

CHAPTER 1
INTRODUCTION

Background

The natural resource base of the Dominican Republic is being degraded at an alarming pace; the annual erosion rate in the majority of watersheds is estimated to average 300 metric tons per hectare (Hartshorn et al., 1981). Roth (1987) points out that massive degradation of watersheds is occurring throughout the country. Every year, millions of tons of soil are washed away as hillside areas are denuded. Hartshorn et al. (1981) offer proof of this statement when they state that sedimentation has reduced, by more than half, the capacity of many multimillion dollar hydroelectric facilities in the Dominican Republic.

Most of the water resources in the Dominican Republic experience severe problems, primarily due to inadequate planning and management, and due to population pressures in sensitive mountain environments. Indiscriminate deforestation, improper road-building, intensive slash and burn agriculture, overgrazing, and poor agricultural practices induce high erosion and sedimentation rates and negatively affect streamflow regimes. The Nizao watershed in the Dominican Republic is representative of this situation (Figure 1.1).

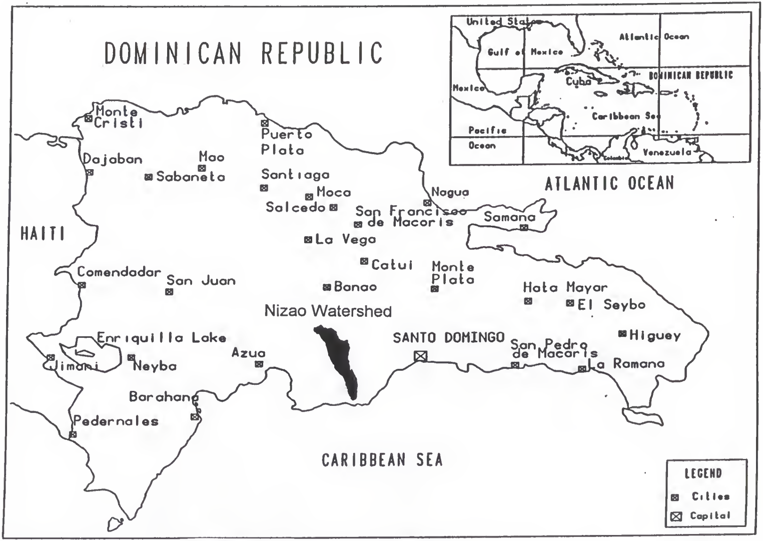


Figure 1.1 Location of Nizao Watershed in Dominican Republic

Present land use patterns in Nizao are inconsistent with the goal of protecting soil resources. In the early 1940s, dense forest vegetation and low population density in upstream areas prevented land degradation problems inthe Nizao basin. However, in the 1950s, commercial logging operations accelerated deforestation in the higher basin elevations (Hansen, 1981), and population pressures increased significantly in the fragile upland environment. Watershed management plans were nonexistent during this accelerated logging phase. Legal logging operations were ceased in 1967 when a new law closed sawmills and prohibited logging. The new law significantly reduced deforestation; however, much damage had already been done.

The prevailing situation in Nizao has occurred because of inadequate resource management policies during the period of intensive watershed exploitation. The Valdesia dam, located in the lower portion of Nizao, was built in 1974 with a reservoir capacity designed to last 50 years. According to Espinal, by 1981, after only 7 years of operations, the Valdesia reservoir had lost 57 percent of sediment storage capacity. Veloz et al. (1985) found that a reduction of sediment loads in Valdesia reservoir could achieve downstream benefits throughout an extension of reservoir lifetime, consisting primarily of the present value of energy produced. However, no sediment reduction has been obtained; thus, Consenso Agrario (1989) reported that Valdesia reservoir had lost 80 percent of its dead storage capacity after 13 years of operations. If the same sedimentation rate continues the abandonment of the reservoir will occur soon.

Nizao watershed increased its importance at this time since two new reservoirs were built there at the end of year of 1992. Jiguey and Aguacate reservoirs are extremely important for the production of hydroelectricity. Jiguey and Aguacate were designed to produce 202 and 208 million KWh of electricity, respectively. These amounts will reduce the current energy deficit suffered by the Dominican Republic. In addition to energy production, Jiguey and Aguacate dams, through streamflow regulation, will help decrease sediment entering the Valdesia reservoir. This will improve Valdesia dam operations, and will increase energy production, irrigation, and the availability of potable water for the capital, Santo Domingo.

The threat that sedimentation has posed to the economic life of Valdesia reservoir also exists for Jiguey and Aguacate reservoirs. Severe sedimentation still threatens to fill their dead storage capacities much sooner than was anticipated by the dam designers. Because of the experience with the Valdesia reservoir, the National Institute of Hydraulic Resources (INDHRI) is dedicating efforts to protect the Nizao watershed from accelerated sedimentation, which would negatively affect the hydroelectricity production of both dams. INDHRI has proposed an integrated management program to reduce sedimentation. Most of the activities proposed in this management plan are distributed within the drainage basin that contains the Aguacate dam. This dam is found between Jiguey dam at the upper region and Valdesia dam at the lower region.

Objectives

This research study is based on the premise that watershed management is an essential component in the development of water resources. This research attempts to estimate the downstream benefits that result from a watershed management approach that reduced soil sedimentation in the Aguacate hydroelectricity dam in the Nizao watershed. To accomplish this, it is hypothesized that:

1. An increase of sediment trapped in the reservoir will reduce its physical outputs of electric energy, and therefore the economic value.
2. A reduction of sedimentation throughout the basin using a watershed management approach will increase the flow and/or value of services drawn from basin water resources.

The specific research objectives are:

1. To determine sedimentation rates in the Aguacate reservoir “with” and “without” watershed management.
2. To estimate the net benefits that will accrue with watershed management implementation.

CHAPTER 2
LITERATURE REVIEW

The Watershed as a Management Unit

According to Dixon and Easter (1986), the watershed is a logical planning unit, since it explicitly forces the recognition that sustained land or resource development depends on the interaction of all activities occurring within the watershed. Within a watershed, uplands and lowlands are physically linked by the hydrologic cycle. Upland activities may create downstream opportunities or problems by influencing the streamflow regime and the production of sediment and other waterborne materials that move through the system. To recognize this fact, one has merely to look at many examples where poor upstream land use practice's result in downstream disasters. Upland erosion not only leads to long-term losses in upland productivity, but also to losses of reservoir storage capacity, which in turn contributes to lost hydropower production, increased flooding, or a downstream loss of irrigation capacity. Soil loss creates adverse downstream impacts even when reservoirs are not present. In other words, the watershed management idea is an integrated way of looking at land and water uses and their interaction in a given region.

Briones (1986) stresses that watersheds also are convenient units for performing economic analyses and for considering the many physical changes linked to resource use and development. Most facets of resource development can be evaluated, including on-site and off-site changes and impacts. Land use activities and upland disturbances often result in a chain of consequences that can be examined and evaluated readily within a watershed framework.

A characteristic unique to the watershed is that it provides the basis for economic analysis and also resource management. Dixon and Easter (1986) contend that strong economic logic exists for using a watershed as an analytical unit. They emphasize that many externalities associated with alternative land-management practices on individual farms are internalized when the watershed is managed as a unit. Hufschmidt (1982) suggests that the main objective of watershed management is to maximize the net socioeconomic benefit of land-use activities in the watershed. He emphasizes that the principal goal is to improve upstream conditions in order to maintain, or increase, existing on-site output levels while reducing the adverse downstream consequences of land-use activities. Dixon and Easter (1986) point out that integrated watershed management is widely recognized as a necessary step in any attempt to prevent or remedy sedimentation problems. Hamilton (1986) emphasizes that a watershed approach toward land and water resource management encompasses the upstream-downstream linkages and provides a good way to internalize externalities.

Hydrologic Model and Soil Erosion

According to Morgan (1986) most of the models used in soil erosion studies are of the empirical type. They are based on defining the most important factors and, through the use of observation, measurement, experiment and statistical techniques, relating them to soil loss. Anderson and Burt (1985) point out all models seek to simplify the complexity of the real world by selectively exaggerating the fundamental aspects of a system at the expense of incidental detail. They agree that, in presenting an approximate view of reality, a model must remain simple enough to understand and use, yet complex enough to be representative of the system being studied.

Several types of models are available for use in evaluating hydrologic responses on a watershed. Yound and Onstad (1984) divided models into two main groups, stochastic and deterministic. Stochastic models are statistically based and operate on the premise of change or the statistical probability of something happening. For a single watershed, if sufficient historic data for watershed are available, and the watershed is not undergoing any major changes in management, the stochastic model can be used to predict what will happen when a parameter such as rainfall amount is changed. They stress that one of difficulties of using this type of model is getting sufficient data for the watershed under study. They also point out that the performance of this type of model is a function of the watershed characteristics and, thus, it cannot be used directly on another watershed. They emphasize that stochastic models are not always the most suitable models for use in evaluating watersheds.

Deterministic models are based on a sequential approach. They consist of several components describing the physical processes taking place within the watershed. Each of the processes or components is associated with one or more watershed characteristics which can be measured. The performance of the model depends upon an adequate description of the physical processes taking play. Morgan (1986) stresses that in theory, it is not necessary to have flow records for the watershed for other than testing. Consequently, deterministic models are best suited for use in estimating the effects of management alternatives within a watershed by assigning modified values for some of the measured characteristics.

Soil Erosion and Reservoir Sedimentation

Soil erosion and sedimentation processes include detachment, transportation and deposition of sediments away from their original positions in the soil mass. The main agents involved are water, gravity, ice and wind. Soil erosion and sedimentation processes due to the agency of water form a central theme of the present study.

Many benefits derived from water resource development in Third World countries have been lost due to soil erosion. Eckholm (1976) agreed that soil erosion is recognized as one major environmental problem facing the Third

World. Southgate (1988) agreed that sediments entering a reservoir are a problem, not simply because they displace storage capacity. He explains that some eroded materials pass through the reservoir and into generators and irrigation systems, thereby damaging turbine blades and other machinery and clogging irrigation canals. Also, sediments tend not to stay in one part of a reservoir, particularly in the narrow, steeply-sloped reservoirs found in mountainous parts of the Third World. Southgate points out that when major siltation has occurred in dam/reservoir complexes, they are frequently abandoned because recuperation is quite costly. According to Sfeir-Younis (1985), sedimentation has eliminated much of the reservoir capacity created in the Third World during the last half century.

Fleming (1982) stresses that water resource projects in developing countries often neglect the effects of upland agricultural use on downstream improvements, particularly reservoirs. He emphasizes that the impacts of sedimentation can seriously decrease the effectiveness of reservoirs, especially in tropical locations.

The amount of energy output generated from a hydropower dam depends on the available storage and the streamflow characteristics. Active reservoir storage capacity will be reduced by an increasing sedimentation rate caused by accelerated erosion. Quezada (1979) shows that the social and economic costs of increasing sedimentation and changes in streamflow characteristics may severely affect the design and operation of existing and projected engineering works, thereby increasing initial costs of investments costs, maintenance and operation.

According to Southgate (1988), a major concern of reservoir managers around the world is the loss of storage capacity due to sedimentation. Furthermore, loss of active storage capacity reduces the value of services obtained from the reservoir. Koelzer (1969) describes a reservoir as a natural resource which should not be wasted by utilization at less than optimum potential. According to Eckholm (1976), a good reservoir site is a nonrenewable resource in the sense that once filled with silt, that particular site is generally irreplaceable.

In a reservoir, the dead storage volume is designed to hold those incoming sediment loads projected to occur during the economic life of the project. However, Quezada (1979) stresses that this criterion fails in mountainous humid tropical areas on two accounts. First, sediment does not necessarily settle only on the dead storage and second, most of the time the amount of sediment deposition is grossly underestimated. Boerboom (1973) emphasizes that this criterion is especially inadequate for tropical countries, where greater access to reservoir sites via new roads opens the way for human invasion of sensitive watershed lands. In a short period, watersheds are often modified drastically by removal of natural vegetation by logging, grazing, and agricultural activities. The main factors related to land invasions are population pressure and lack of institutional and/or legal mechanisms necessary to adequately protect the watershed lands. Some examples can illustrate the difficulties for many developing countries. The Anchicaya Dam in Colombia was one-quarter filled with sediments after only 21 months, and three-quarters filled after only 10 years of use (Allen, 1972). A survey of 132 dams constructed 30 to 50 years ago in Masvingo, Zimbabwe, suggests that over half were more than 50% filled with silt (Elwell, 1985). Morris (1986) observes that the most vexing water supply problem in Puerto Rico is reservoir sedimentation; and the most critical problem occurs at the Carraizo and La Plata reservoirs which provide two-thirds of the water supply for the San Juan metropolitan area. He agrees that Carraizo and La Plata reservoirs are expected to fill by 2010 and 2060 respectively, and electricity production will decline substantially well before complete sedimentation.

Heavy tropical rains, steep slopes, and the state of watershed soils and vegetation all contribute to elevated sedimentation rates. According to Reuter et al. (1986) sedimentation must be considered a major factor in the longevity and environmental condition of reservoirs. They agree that the extent to which erosion is controlled in the drainage area can greatly influence the reservoir sedimentation rates and the lifespan of dams.

Land Management Practices and Soil Erosion

Erosion generally is not a major problem on well-protected tropical watersheds. However, accelerated erosion usually takes place when tropical forest land on steep mountain slopes is cleared for agricultural purposes. As settlements are established, roads are built, which, in these sensitive environments, compound the soil erosion problem. According to Quezada (1979), inadequate land use management may severely affect reservoir performance since increases in erosion will accelerate the sedimentation rate, thereby reducing the active reservoir capacity.

Lack of vegetative cover creates splash erosion. Erosion increases with the amount of bare soil in a watershed. Simmons (1988) confirms this in a study that defines sediment characteristics in North Carolina streams during the period 1970 to 1979. He found that mean suspended sediment yields from rural agricultural watersheds were six times greater than yields from forested watersheds.

An inappropriate land use accelerates the erosion rate beyond the tolerable level. According to Lal (1990), forested lands have comparatively less erosion risk than farm lands or plantation crops. He asserts that this is particularly true if the forested lands have undulating to steep terrain. He states that when all other factors remain the same, land uses susceptible to erosion may be ranked in descending order as follows: bare fallow, arable land, perennial crops, grass cover, natural vegetation. Shallow (cited by Lal,1990) found that the soil erosion rate increased from 0.24t/ha/yr under natural forest to 4.9t/ha/yr under mature coffee and 7.32t/ha/yr under vegetables.

Several studies have been conducted to estimate how different land management practices affect erosion and sediment transport in agricultural watersheds. In southeast Nebraska, Ravavian (1990) reports that nonstructural (agronomic) management practices has a greater impact in controlling erosion and non-point source pollution than do structurally oriented practices. Hill (1991) states that average sediment yields from watersheds using best land-management practices are only about one-seventh of those from watersheds using standard land-management practices. Hardjono (1980) reports on reforestation benefits in Indonesia, from small watersheds reforested with four different species. He observes sediment yields from reforested areas to be one-third of those from agricultural watershed. Hamilton (1983) argues that even introducing trees into grazing or cropping land in a well-managed agroforestry system can effectively reduce sedimentation.

Crowder and Yound (1985) show soil and nutrient losses and the cost effectiveness of conservation practices for typical fields in the Conestoga headwaters. Setia and Magleby (1988) observe the cost effectiveness of alternative agricultural practices for reducing sediment and nutrient loading in Illinois watershed. Prato et al. (1989) identify economically efficient management practices for controlling agricultural erosion and water pollution in Idaho watersheds. Morris (1986) emphasizes that the reservoir sedimentation problem in Puerto Rico is mainly caused by actual land management practices.

Reuter et al. (1986) asserts that it is critical that reservoir management pay special attention to soil conservation and the regeneration of protective forest and associated vegetation in upstream areas. They emphasize that newly created reservoirs and their associated upstream areas within tropical regions become a focus of increased human activities. Thus, land-use practices within the drainage area have a direct and significant impact on the socio-economic and ecological benefits provided by these hydrologic systems.

Hamilton and King (1983) emphasize that watershed rehabilitation through reforestation or afforestation indeed can cause major reductions in stream sediment loads. In this respect they consider it is particularly important to stabilize landslip-prone areas with forest trees. They stress that one real benefit from reforestation or afforestation is to reduce the erosion rates that prevail under most other land systems.

Benefits of Sedimentation Reduction

According to Southgate and Macke (1988), the downstream benefits of soil conservation can be placed in one of three categories. First, reduced sedimentation increases the flow and/or value of services drawn from water resources. Second, watershed management reduces the need for downstream remedial efforts, such as dredging and water treatment. Third, erosion control reduces damage to machinery utilized in water resource development projects.

Enhancement of the value of energy production throughout a dam's useful lifetime occurs when the rate at which sediment displaces water storage capacity is reduced by erosion control. Southgate (1990) stresses that reservoir volumes in tropical and subtropical areas are often small compared with sedimentation loads. Consequently, rapid sedimentation often forces the abandonment of reservoirs before the end of their useful lifetime. Given these circumstances, the benefits of extending reservoir lifetime through improved watershed management systems are more significant. Dixon and Easter (1986) stress that integrated watershed management is widely recognized as a necessary part in any attempt to prevent or remedy sedimentation problems.

Veloz and Southgate (1991) emphasize that dredging or flushing sediments to increase water storage capacity in a reservoir is, in general, uneconomical. Allen (1972) agrees that this technique, unfortunately, can be quite costly and its benefits are sometimes short-lived. Veloz et al. (1985) stress that another downstream benefit of erosion control arises because sedimentation reduction results in machinery which functions better and requires less frequent repair and replacement.

Land management programs would reduce reservoir sedimentation. Fleming (1982) found, in environmental and economic impacts studies completed on the Poza Honda watershed in Ecuador that, substantial economic benefits accrue from reducing reservoir sedimentation through a conservation program. An erosion control program costing $1.8 million will result in project benefits totaling more than $30 million. He emphasized that the impacts of sedimentation can adversely affect the benefit/cost ratio.

Economic Analysis in a Watershed Project

The principal interest of economic analysis of watersheds has been focused on project and management practice appraisal. It is applied in a benefit-cost and project evaluation framework to help managers and planners select alternatives under set of constraints. These alternatives are evaluated for best options (Hufschmidt, 1982). Flemming (1982) points out that attention is being given to benefit-cost approaches of the erosion-sedimentation interaction in major water resource development projects.

Physical and economic activities within a watershed are closely related through the ways in which the resources are used. Management decisions, with impacts on land and related hydrologic resources, are likely to be influenced by multiple objectives. Dixon and Easter (1986) point out that an economic analysis is only one part of the watershed management process, but they stress that just as it is important to get the facts straight on the physical aspects of a project, one should also have the project economics clearly defined.

Benefit-cost theory emerged in the late 19th century because of proposal evaluations for wastewater disposal systems. As defined by Merkhofer (1987), benefit-cost theory identifies a best alternative in terms of an efficiency criterion that specifies both how advantages and disadvantages to individuals should be measured and how they should be aggregated to obtain an overall measure of social good.

Benefit-cost analysis (BCA), the application of benefit-cost theory, was first conducted by the Corps of Engineers on water resource projects and achieved statutorial authority with passage of the Rivers and Harbors Act (1902) and the Flood Control Act of 1936 (Thompson, 1980). In these early years, BCA consisted of little more than identifying main program effects, somehow placing a monetary value on the benefits and costs and, then, comparing them through simple division or subtraction. Since then, BCA has become more sophisticated and has been applied to a variety of program areas, many of which are related to natural resources.

Benefit-cost approaches strive to set up the efficiency criterion of benefit-cost theory (Merkhofer, 1987). This is accomplished by determining whether the consequences of an alternative are likely to increase net present value (NPV). An economic analysis can inform decision-makers whether or not the project is justified on an economic efficiency basis.

Sheng (1990) focuses on the cost and benefit analysis as an important technique that systematically compares the streams of costs and benefits to determine economic efficiency or worth of a project. He describes briefly three measures for cost benefit analysis using the same input data and assumption, as follows: 1) Net Present Value (NPV), this measure is used to find the present value of net benefits of a project, i.e., the difference between the present value of the stream of benefits and the present value of the costs. A project may be accepted if this difference is zero or positive ($B-C \geq 0$, where B and C are discounted). To compare several alternatives, the analysis results can be ranked for decision making. 2) Benefit and Cost Ratio (B/C ratio), this measure determines a ratio using present value of all the benefits in the numerator and the present value of the costs in the denominator. A project is considered to be economically sound or acceptable when the calculated value is larger than or at least equal to 1 ($B/C \geq 1$). This result also can be shown as a ranking of alternatives. 3) Internal Rate of Return (IRR), this is the discount rate, which, when applied to the stream of benefits and costs, produces an equal present value of both or a net present value of zero (A discount rate when B=C, or B-C=0). This rate is called IRR and represents the average earning power of the project's investment to be compared with other investments.

With and Without Project Analysis

Comparing the impact "with" and "without" project is a normal technique to determine a project's worth. Their difference is the net additional benefit arising from the proposed project (Sheng, 1990).

To determine the "without" project situation, the existing condition over time and into the future first must be defined and quantified for the watershed system using available inventory, monitoring and survey data. The next step in the analysis requires that the "with project" conditions be defined. The effectiveness of different rehabilitation and management practices must be quantified (Gregersen et al., 1987). The appropriate comparison is between what the situation will be if the project is carried out as compared to if there is no project.

CHAPTER 3
MODEL DESCRIPTION

Hydrologic Model

In order to predict both erosion and sediment yield a deterministic model, the Simulator for Water Resources in Rural Basins (SWRRB), is used. It was developed to simulate hydrologic and related processes in rural basins and is primarily based on consideration of the physical factors governing basin hydrology. The model is a modification of the CREAMS daily rainfall hydrology model (Williams and Nicks, 1982). According to Arnold and Sammons (1988), the major changes involved were (1) model expansion to allow simultaneous computations in several sub-basins, and (2) additional components to simulate weather, return flow, pond and reservoir storage, crop growth, transmission losses, and sediment movement through ponds, reservoirs, streams, and valleys. SWRRB was developed by researchers of the Soil and Water Research Laboratory in Temple, Texas, through the United States Department of Agriculture Research Service (USDA-ARS).

Arnold and Williams (1985) employed SWRRB to predict the effects of management decisions on water and sediment yields, with reasonable accuracy.

The results of their tests on widely varying watersheds showed that SWRRB can realistically simulate water and sediment yields under a wide range of soil, climatic, land use, topographic, and management conditions. The authors suggest that SWRRB should provide a versatile and convenient tool to plan and design water resource projects. Borah (1990) agrees that the SWRRB model has been reasonably tested and evaluated in a good number of watersheds with different physical and climatic conditions. She emphasizes that the model provides a useful tool to predict the effect of management decisions on water and sediment yields for ungaged, rural basins. SWRRB has been validated on basins up to 500 km^2 (Arnold and Williams, 1987).

Model Operation

According to Arnold et al. (1990), some convenient features of SWRRB model include: special input data forms that are used with an interactive data entry system, operates on a daily time step, and the model can be run on a variety of computers since storage requirements are only 124 kilobytes. SWRRB operates a main program and 36 subroutines under FORTRAN Program. The main program initializes variables, does all the input and output operations, controls the daily simulation of each sub-basin by calling the appropriate subroutines, accumulates monthly and annual values, and computes average values for the simulation period. A simplified model flow chart is shown in Figure 3.1.

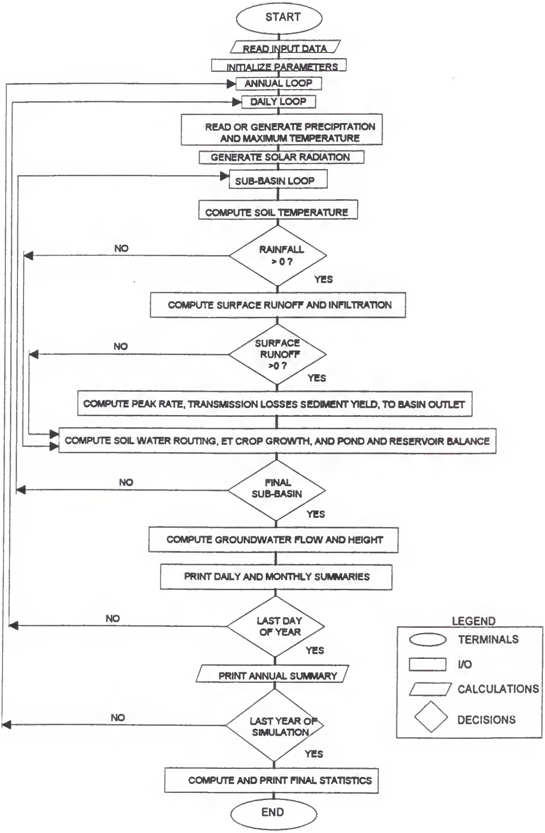

START
READ INPUT DATA
INITIALIZE PARAMETERS
ANNUAL LOOP
DAILY LOOP
READ OR GENERATE PRECIPITATION AND MAXIMUM TEMPERATURE
GENERATE SOLAR RADIATION
SUB-BASIN LOOP
COMPUTE SOIL TEMPERATURE
RAINFALL >0 ?
NO
YES
COMPUTE SURFACE RUNOFF AND INFILTRATION
SURFACE RUNOFF >0 ?
NO
YES
COMPUTE PEAK RATE, TRANSMISSION LOSSES SEDIMENT YIELD, TO BASIN OUTLET
COMPUTE SOIL WATER ROUTING, ET CROP GROWTH, AND POND AND RESERVOIR BALANCE
FINAL SUB-BASIN
NO
YES
COMPUTE GROUNDWATER FLOW AND HEIGHT
PRINT DAILY AND MONTHLY SUMMARIES
LAST DAY OF YEAR
NO
YES
PRINT ANNUAL SUMMARY
LAST YEAR OF SIMULATION
NO
YES
COMPUTE AND PRINT FINAL STATISTICS
END
LEGEND
TERMINALS
I/O
CALCULATIONS
DECISIONS

Figure 3.1. Hydrologic Model Operation Flow Chart

Model Components

The components of SWRRB can be posted into three major divisions: hydrology, weather, sedimentation yield. Arnold et al. (1990, 1992) have given a detailed description of the SWRRB components. A brief description of each is presented below. Appendix 3.A shows the model input requirements with the variables definitions, units and the typical ranges of the model operation.

Hydrology . Hydrologic processes included are: surface runoff, peak flow, percolation, lateral subsurface runoff, evapotranspiration, transmission losses, pond and reservoir storage and crop growth.

Surface runoff is predicted separately for each subarea and then routed to obtain the total basin runoff. The proportion of daily rainfall contributing to surface runoff is predicted using the Soil Conservation Service curve number equation (USDA, 1972):

$$Q = (R - 0.2s)^2 /(R + 0.8s) \qquad (1)$$

in which Q = daily runoff in mm; R = daily rainfall in mm; and s = a retention parameter in mm. The retention parameter, s, is related to curve number (CN) using SCS equation:

$$s = 254(100/CN-1) \qquad (2)$$

The constant, 254, in Eq.2 gives s in mm. The average curve number (CN) can be obtained for any area using the SCS Hydrology Handbook (USDA, 1972).

Peak runoff rate predictions are based through a modification of The Rational Formula (Williams et al. 1984):

$$q_p = (\alpha)(Q)(A)/360(t_c) \qquad (3)$$

in which q_p = peak runoff rate in $m^3.s^{-1}$; α = a dimensionless parameter that expresses the fraction of total rainfall that occurs during the watershed time of concentration, t_c in hours; Q is the daily runoff in mm; and A = watershed area in square kilometer. The time of concentration can be estimated by adding the surface and channel flow times.

$$t_c = t_{cc} + t_{cs} \qquad (4)$$

Where t_{cc} is the time of concentration for channel flow and t_{cs} is the time of concentration for surface flow in hours.

Percolation component is a storage routing technique to predict flow through each soil layer in the root zone. Subsurface runoff is calculated simultaneously with percolation. A nonlinear function of lateral flow travel time is used to simulate the horizontal component of subsurface flow. Percolation is computed using the equation:

$$O = SW_0 [1\text{-}\exp(-\Delta t/TT)] \qquad (5)$$

where O is percolation rate in $mm.d^{-1}$; SW_0 is soil water content at the beginning of the day in mm; Δt is the time interval (24h) and TT is the travel time through layer in hours.

Evapotranspiration computations are based on the concepts of Ritchie's ET model (Richie, 1972). Potential evapotranspiration is estimated by the Priestley and Taylor (1972) method. Required inputs are daily maximum and minimum air temperature and solar radiation. To compute potential evaporation the model uses the equation:

$$E_0 = 1.28\ [(RA)(1-AB)/58.3]\ [\delta /(\delta +0.68)] \qquad (6)$$

where E_0 is the potential evaporation rate in $mm.d^{-1}$; RA is the daily solar radiation in Langley; AB is the albedo; and δ the slope of saturation vapor pressure curve at the mean air temperature.

Transmission losses are calculated according to Lane's method, as described in Hydrology Handbook (USDA, 1983). Channel losses are estimated as functions of channel width and length, and flow duration. Both runoff volume and peak rate are adjusted accordingly when transmission losses occur.

Weather. SWRRB includes a weather generator that allows the simulation of daily precipitation and temperature when measured daily values are not available. The weather variables necessary for driving this model are monthly means and standard deviations of precipitation characteristics, air temperature, and solar radiation. In solar radiation parameter, one set of weather variables may be simulated for the entire basin, or they can be simulated for each sub-basin separately.

The SWRRB precipitation model was developed by Nicks (1974). The input to the model includes monthly probabilities of receiving precipitation if the previous day was dry and if the previous was wet. Given these transition probabilities, the model stimulates sequences of wet and dry days. If the transition probabilities are not available, they can be estimated using the average number of days of precipitation,

$$P(W|D)_j = 0.75 dp_j/dm_j \tag{7}$$

$$P(W|W)_j = 0.25 + P(W|D) \tag{8}$$

where P(W|D) is the probability of rainfall after a dry day, P(W|W) is the probability of rainfall after a wet day, dp is the days of precipitation in month $_j$, and dm is the number of days in month $_j$. When a precipitation event occurs, the amount is determined by generating from a skewed normal daily distribution.

SWRRB generates daily maximum and minimum air temperature, daily precipitation and solar radiation using a normal distribution corrected for wet-dry probability state (Nicks and Harp, 1980). The correction factor is used to provide greater deviation in temperatures and radiation when the weather changes and during rainy days. Conversely, deviations are smaller on dry days. The correction factors are calculated to insure that long-term standard deviations are maintained. Monthly values of daily standard deviations of maximum and minimum temperature are input. Monthly values of daily standard deviations of solar radiation are estimated by assuming that the difference between mean and maximum daily radiation is four standard deviation.

Sediment Yields. SWRRB simulates sediment yields using the Modified Universal Soil Loss Equation (MUSLE) (Williams and Berndt, 1977) and a sediment routing model. The MUSLE considers both surface erosion and sediment movement in the catchment (Kothyari et al., 1994). Sediment yield is computed for each sub-basin. MUSLE uses Universal Soil Loss Equation parameters except for the rainfall erosivity term which is replaced by a runoff erosivity term. The expression is

$$SY = 11.8\ (Vq_p)0.56\ (K)(C)(PE)(LS) \qquad (9)$$

where SY is the sediment yield (ton/ha) from the sub-basin in time t (year); V is the surface runoff volume for the sub-basin in m^3; q_p is the peak flow rate for the sub-basin in $m^3.s^{-1}$; K is the soil erodibility factor; C is the crop management factor; PE is the erosion control practice factor; and LS is the slope length and steepness factor.

The crop management factor, C, is evaluated for all days when runoff occurs using the equation:

$$C= \exp[(-0.2231-CVM)\ \exp(-0.00115CV) + CVM] \qquad (10)$$

where CV is the soil cover in kg/ha and CVM is the minimum value of C. The value of CVM is estimated from the average annual C factor.

K values are contained in the Handbook No.537, U.S. Department of Agriculture (Wischemeier and Smith, 1978), and PE factors can be estimated for each sub-basin using information contained in National Engineering Handbook, USDA,1972.

The LS factor is computed using the equation (Wischmeier and Smith, . 1978):

$$LS = (\lambda / 22.1)^{\xi}\ (65.41S^2 + 4.56S + 0.065) \qquad (11)$$

where λ is slope length, the exponent ξ varies with slope and is computed in SWRRB with the equation:

$$\xi = 0.6\ [1 - \exp(-35.835\ S)] \qquad (12)$$

Sediment outflow is computed by considering the sediment budget and an equilibrium sediment concentration, computed empirically. The sediment routing through channels and over floodplain consists of computing deposition and degradation simultaneously. Deposition is based on fall velocity, and degradation is based on stream power from Bagnold (1977).

The sediment volume and particle size distribution of the sediment reaching the sub-basin outlet is estimated using an empirically related sediment delivery ratio and a routing coefficient technique of Williams et al., (1985).

Economic Model

A benefit-cost approach is employed to estimate the economic values of the products of different land-use types under two different management options. According to Bojö (1991) this constitutes a coherent method to organize information about social advantages (benefits) and disadvantages (costs) in terms of a common monetary unit.

The economic feasibility of the activity is evaluated using the Net Present Value (NPV), and Benefit-Cost ratio. The NPV is one of the most widely used formulas in project analysis. The NPV formula determines the present value of net benefits (total benefits minus costs) by discounting the streams of costs and benefits back to the beginning of the base year. The simple formal statement of net present value used in benefit-cost analysis (BCA) is

$$NPV = \sum_{t=0}^{n} (B_t - C_t)\,(1+r)^{-t} \qquad (15)$$

where NPV is net present value; n is the number of years used in the project analysis; t is the relevant project year; B_t is total benefits in year t; C_t is the total costs in year t; and r is the interest rate or discount rate, expressed as a decimal.

The benefit-cost ratio compares discounted benefits B to discounted costs C. If the B/C ratio is greater than 1, then the discounted benefits outweigh the discounted costs, and the project will generate net benefits over its lifetime. When the B/C ratio is exactly equal to 1 means that discounted benefits exactly equal discounted costs and over its lifetime the project will produce zero net benefits. The benefit-cost ratio formula is a simple derivative of the net present value criterion:

$$B/C \text{ ratio} = \Big[\sum_{t=0}^{n} B_t/(1+r)^t\Big] \Big/ \Big[\sum_{t=0}^{n} C_t/(1+r)^t\Big] \qquad (16)$$

CHAPTER 4
MATERIALS AND METHODS

Study Area

Nizao Watershed

The Aguacate drainage basin, which is the principal study area for this research, comprises the headwaters of the larger Nizao watershed (Figure 4.1). Located between 18°15' and 18°45' N and 70°15' to 70°13' W, on the southeastern flank of the Central Cordillera, it is one of the more important basins of the Dominican Republic. The Nizao basin, is the second most important in the country in terms of hydropower potential, accounting for 34 percent of its total planned hydropower capacity (De la Fuente, 1976). The main channel of the Nizao is 122 kilometers in length. The most important tributaries are: Malo, Banilejo, Mahoma, Mahomita and Jiguey. These latter two constitute the main streams of the Aguacate basin.

Three important dams have been built in the Nizao watershed during the last 25 years. Valdesia, completed in1974, and the Jiguey and Aguacate dams finished in 1992 (Figure 4.1). The older Valdesia dam produces electricity, irrigation and drinking water while the Jiguey and Aguacate are dedicated to electricity production.

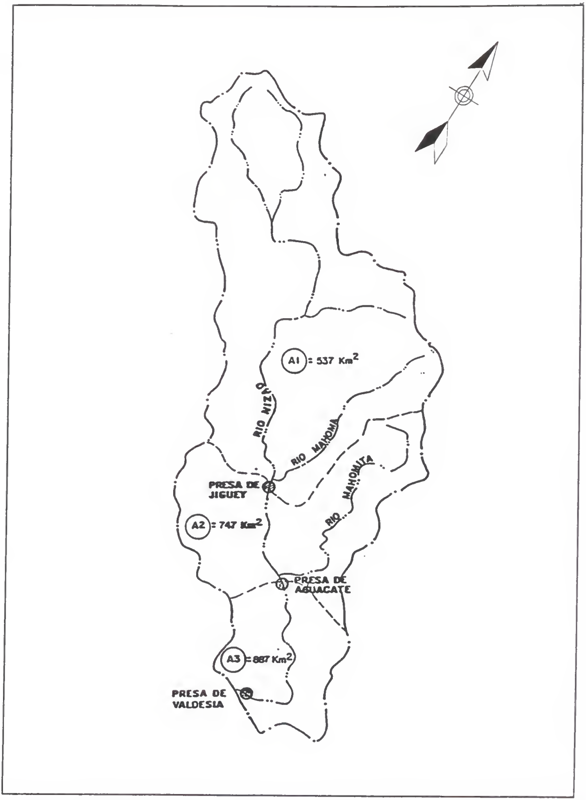


Figure 4.1 Nizao Watershed Location, and Jiguey, Aguacate and Vadesia Dams

Aguacate Basin Description. The Aguacate drainage basin is located in the middle lower part of Nizao watershed. It occupies 213.1 km^2 area, or approximately 25 percent of Nizao watershed above the Valdesia dam site. It is comprised of two sub-basins. The first, Mahomita River, occupies an area of 114.8 km^2 with a main stream length of 30.1 km. The second, Jiguey River, joins the Nizao 7 km above the Aguacate dam site; it is only 10 km long but drains an area of 98.4 km^2. Figure 4.2 presents the Aguacate basin and its two sub-basins and the drainage network for each sub-basin is also shown.

Elevations vary from 1400 m near the source of the Mahomita River, to 297 m at the base of the dam.

Soils are mostly Lithic Troporthents (Agrohorti, 1988), formed by materials weathered from metamorphic and igneous rocks. They are shallow and well drained with loamy to sandy textures. Few areas have Typic Dystropets or Typic Tropudults, which are moderately to well developed, moderately deep, sandy loamy to clayey textured soils. These soils are formed in material weathered from metamorphic and sedimentary rocks.

The region has a subtropical climate. The mean annual rainfall of 1738 mm is distributed into dry and wet seasons. The dry season, from December to April and the wet, accounting for over 78 percent of the annual total, for the remainder of the year, including a diminution of precipitation during the month

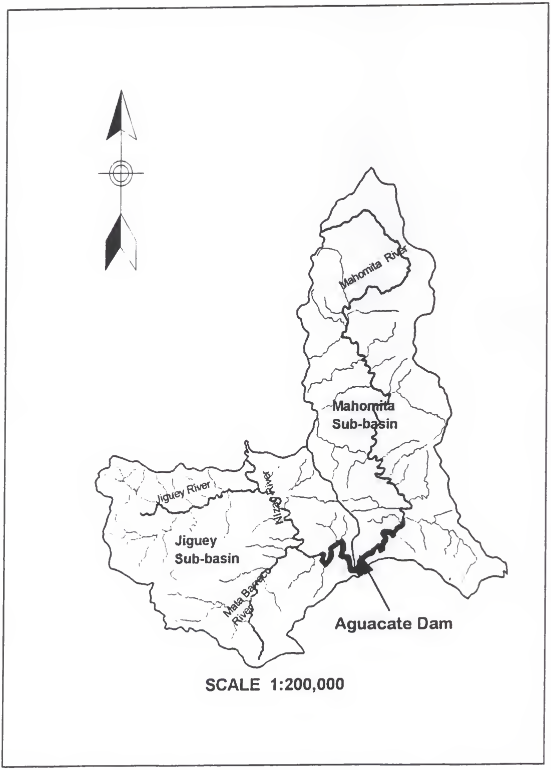


Figure 4.2. Drainage Network for Aguacate Basin

of July (Figure 4.3). May (236.7 mm) and June (231.3 mm) have the highest precipitation, and January (60.4 mm) and February (59.3 mm) have the lowest. Rainfall summaries are presented in Table A-1. Figure 4.4 reveals that temperatures are relatively constant throughout the year, with highest values in July (31.3^{0}C) and the lowest in January (28.4^{0}C). Daily minima peak in July and August (23.1^{0}C and 23.2^{0}C respectively) and are lowest in January and February (20.0^{0}C).

Aguacate Dam Characteristics. Construction of the Aguacate dam started in 1987 and was completed in September 1992. It is a cement-filled structure 68 m high. Its normal operating range is between elevations of 324 and 329 m. The drainage area above the Aguacate dam is 213.1 km^2. In the first year of operation, the reservoir capacity was 4.3 million m^3 at an elevation of 329 m above sea-level.

The main function of the dam is to provide electricity. The power plant has an installed capacity of 52 MW. The maximum operating level is at elevation 329 m, while the minimum is at 324m. The water intake device is at 322.6 m. Mean annual energy production is estimated at 208 GWH. (Castellanos and Iturbides, 1993).

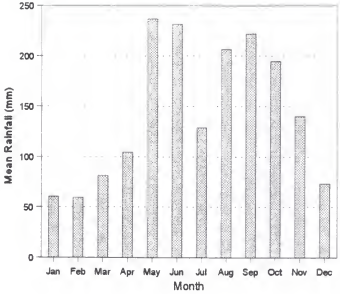


Figure 4.3 Monthly Mean Rainfall for Valdesia Station

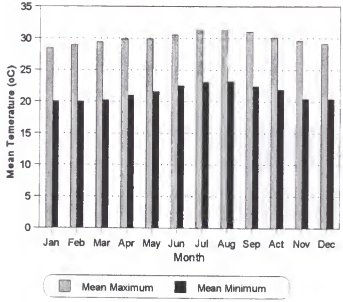


Figure 4.4 Monthly Mean Maximum and Miminum Temperatures for Valdesia Station

Methodology

Data Sources

Several sources of data were used in order to accomplish the research objectives. A primary data source is the Nizao Watershed Natural Resources Inventory (Agrohorti,1988). This author participated as a principal investigator in the study.

The Nizao study describes physical characteristics of the region, such as soil type, land use, slope, geology, geomorphology, hydrology, and presents some climatic data. The study also describes socio-economic characteristics of the watershed. The majority of the data were obtained from field surveys, although additional information was collected from Dominican institutions. Maps provide base line information that has been digitized and entered into a Geography Information System (GIS).

Another important source of information for this research was Watershed Management Plan for Nizao (Amaya,1992).This plan contains detailed information about the proposed land use within the basin and includes costs for future project implementation.

Additional hydrologic and economic data were collected during two field trips to Dominican Republic during in 1992 and 1993. Climatic and hydrologic information were available from the División de Hidrología of the INDRHI. Although several climatological stations are located within the Nizao watershed, only the Valdesia station has a sufficient period of continous record for analysis

(1973-1992). This station is located at 18° 24' 30" N and 70° 15' 50" W, at an elevation of 160 masl.

Aerial photographs for 1966-68 (1:20,000 scale) and 1983-84 (1:40,000 scale), and topographic maps (1:50,000 scale) are available from the Instituto Geográfico Universitario in the Dominican Republic.

The geographic information system, PC ARC/INFO package Version 3.4.1 (ESRI, 1991) is used to assemble the spatial data needed to determine the sediment yield using SWRRB model. Soil type, topography, land use, drainage network, hydrological subdivisions (micro-basins), and sub-watershed boundaries maps are extracted from the various sources and digitized.

Land Management Scenarios

Land development impacts on sediment generation are investigated in this research through the establishment of land management scenarios which incorporate variations in land use and conservation practices. These scenarios are investigated through manipulation of the corresponding GIS coverages required to run the hydrologic model. Two scenarios are established, one corresponds to the land use at the time of the dam construction in 1992. The pertinent data are extracted from Agrohorti (1988) and Amaya (1992).

To determine the best alternative proposed management plan; the analysis combines potential land use with the current land use (1992) map. The overlay analysis is done with the ARC/INFO package (ESRI, 1991) and identification critical areas that require land use changes and the introduction of conservation practices to reduce sedimentation in the basin.

Sediment Model Implementation

Several initial conditions need to be established and parameters estimated before the sediment yield prediction model may be run.

The Aguacate sub-basins, Jiguey and Mahomita, are divided into micro-basins, six for Jiguey and eight for Mahomita. Each micro-basin constitutes a relatively homogeneous hydrologic-geomorphic area.

Climate data are inputted for the entire watershed. Historic daily precipitation data are available, but because of missing mean daily temperatures, it was necessary to input mean monthly minimum and maximum temperatures and to permit the model to generate daily values from the long-term mean monthly temperatures. Monthly maximum 30 minute rainfall intensities at Valdesia are available in the period 1971-75. The 10 year return period rainfall for 0.5 and 6 hour periods are obtained from SEA-IICA (1982).

Soil parameters are derived from the semi-detailed soil survey of the region (Agrohorti, 1988). The soil types are inputted by each sub-basin and the soil parameters required for the model are inputted for each soil horizon. The following soil parameters are required: a) depth (mm) to the bottom of layer, b) available water capacity (mm), c) saturated hydraulic conductivity (mm/hr), d) clay content (percent), and e) soil passing the #200 sieve (percent).

Soil erodibility (K), a measure of the soil's susceptibility to erosion, is determined by the resistance to detachment by rainfall and/or flowing water, and is function of soil infiltration capacity. Calculations are carried out using the Soil Erodibility Nomograph of Wischmeier and Smith (1978), see Figure A-1. Soil erodibility of each soil type is very dependent on the characteristics of surface soil horizon, content of organic matter, permeability classes, content of very fine sand plus silt and clay, and soil structure class.

The cover factor © accounts for the effects of plant cover.
C factor values are calculated for each land use category, under both current (1992) and proposed land uses. These calculations were completed according to the USDA (1980), and Santana (1981). (Santana is an adaptation of the USDA (1980) to the conditions in the Dominican Republic).

Estimated runoff volumes are based on the SCS curve number method (USDA, 1972). The curve number (CN) retention parameter depends upon land use, soil type, and hydrologic soil group (HSG). The curve number (CN) values are generated using information available for the study area (Agrohorti, 1988). First, soil characteristics are used to determine hydrologic soil group (HSG). A hydrologic soil group map is generated and then overlaid with each land use scenarios, under both the current (1992) and proposed conditions. The CN values are weighted by each micro-basins.

Economic Approach

The benefit-cost analysis employed in this research is similar to the approach used by Brooks et al. (1982) in a watershed study in Morocco. Technical details and guidelines are provided in Hufschmidt et al. (1983), Gittenger (1982) and Bojö (1991).

To determine the downstream benefits of the proposed project in the Aguacate basin, it is necessary to analyze two separate relationships. First, the relationship between the two watershed management alternatives ("with" and "without") and sediment deposition in the reservoir using the SWRRB physical model. Second, it is necessary to develop the relationship between sediment deposition in the reservoir and net downstream economic benefits. This approach treats benefits as a direct function of increased reservoir storage capacity and economic life-time resulting from reduced sedimentation.

Net Present Values (NPVs) are determined using the computer program, @RISK (Palisade Corporation,1992), a spreadsheet add-on. NPVs for the reservoir life-time, at specific discount rates, as inputs into of the model are determined using the unit annual benefit values and the annual value losses due to the reduction of the storage capacity. The accumulation of sediment in the reservoir reduces the physical outputs and economic value. Once the physical losses are quantified, they are monetized.

For electrical energy purpose, benefits are considered a direct function of the volume of storage capacity of the Aguacate dam. Therefore, it is possible to derive a benefit for energy in terms of dollars per cubic meter of storage capacity. These values are used to compute the economic losses associated with the reduction of storage capacity. All reductions in storage volume are attributed to sedimentation.

CHAPTER 5
RESULTS AND DISCUSSION

Presented in this chapter are estimates of the sedimentation rates at Aguacate Dam using the simulation hydrological model, described in the preceding chapter. Two different sediment rates are determined using "without" and "with" the watershed management project. This information provides the basis for the estimation of losses of reservoir storage capacity. Once the physical losses were estimated, the next step is to put monetary value on this information. To determine this, any reduction in the designed storage capacity is considered as a loss attributed to sedimentation. Then, using the computed unit benefit values, the values of the loss due to the reduction of the storage reservoir capacity are calculated. The benefits derived with watershed management are calculated in terms of losses avoided in hydropower storage. To show the benefits, the "without" and "with" watershed management scenarios are compared.

Sedimentation Rates

Estimated sedimentation rates from runs of the SWRRB model for Aguacate basin are presented under each of two scenarios. First, the current land use ("without" project) is employed, followed by a run employing the proposed land use ("with" project). Those parameters of the model that vary according to the land use scenario are presented later.

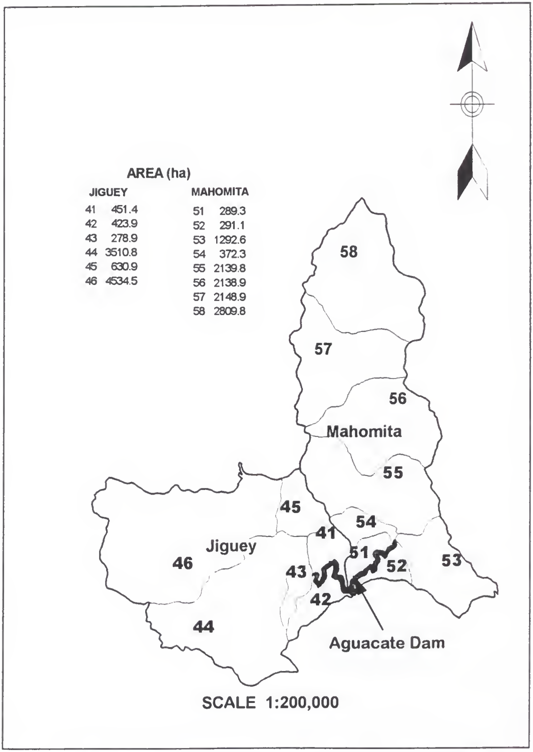
Sedimentation rates are calculated separately for the Jiguey and Mahomita sub-basins. In order to furnish a detailed explanation the model results are shown for each micro-basin by sub-basin. Figure 5.1 maps each micro-basin with its respective identification number (ID#) for the complete basin. These ID#s are used as reference for future discussion; those micro-basins that belong to Jiguey sub-basin are identified by the starting digit 4, while that those that belong to Mahomita sub-basin are identified starting by the digit 5. Area in hectares is also shown for each micro-basin.

Land Management Alternatives

In order to determine the best alternative proposed management plan it was necessary to compare the potential land use with the current (1992) land use. This overlay process was completed with the ARC/INFO package (Version 3.41D, 1991) and the resultant map allowed the location of critical areas in which land use changes and conservation practices are required to reduce the sedimentation rate within the basin.

Potential land use

Four potential land use categories are identified: a) protection, b) forestry, c) silvo-pastoral and, c) agroforestry. The protection category is represented by forest lands with permanent plantation and no commercial use.



AREA (ha)

JIGUEY		MAHOMITA	
41	451.4	51	289.3
42	423.9	52	291.1
43	278.9	53	1292.6
44	3510.8	54	372.3
45	630.9	55	2139.8
46	4534.5	56	2138.9
		57	2148.9
		58	2809.8

Figure 5.1 Micro-basins Identification by Sub-basin in Aguacate Basin

Their sole purpose is to protect the most vulnerable portions of the drainage basin from excessive erosion. The forestry category includes lands that could be in forestry plantation for commercial use. Areas of silvo-pastoral activity are recommended for a combination of improved pasture and forest plantation, while those of agroforestry represent lands that could support various combinations of land use, including crops, permanent fruit plants and forest plantations.

Areas under each of the potential land uses for Aguacate basin are shown in Table 5.1. More than 15,172 ha (61 percent) of the complete basin has forestry capability, 7,931 ha for commercial forestry and 7,242 for permanent forest dedicated to protection forestry. The Mahomita sub-basin has the biggest area suggested for protection (5,884 ha or 27.6 percent of the complete basin). The largest recommended land use in Jiguey sub-basin appears to be commercial forest plantation (6,747 ha; 31.7 percent); while the greatest area displaying a capability for agroforestry is found in Mahomita sub-basin (4,415 ha; 20.7 percent).

Table 5.1 Potential Land Use for Aguacate Basin

Potential	Mahomita		Jiguey		Total Basin	
Land Use	(ha)	(%)	(ha)	(%)	(ha)	(%)
Agroforestry	4,415.2	38.5	922.5	9.4	5,337.7	25.0
Forestry	1,183.1	10.3	6,747.4	68.6	7,930.5	37.2
Silvopastoral	0.0	0.0	803.1	8.2	803.1	3.8
Protection	5,884.4	51.2	1,357.4	13.8	7,241.8	34.0
Total	11,482.7	100.0	9,830.4	100.0	21,313.1	100.0

Current land use

By contrast Table 5.2 shows current land use (1992) in the Aguacate drainage basin. Five categories have been differentiated for this study. The most common land use in the basin is coffee with 8,594 ha (40.3 percent), of which 5,597 ha are concentrated in Mahomita sub-basin. Despite its mountainous terrain, agriculture crops cover almost one third (6,906 ha) of the Aguacate basin area. Jiguey's percentage of land in crops is almost double that of Mahomita sub-basin (43.9 and 22.6 percent). Moreover, only 2,840 ha (13.3 percent) are covered in natural forest, and pasture and scrub represent 11.8 and 2.1 percent, respectively.

Table 5.2 Current Land use (1992) for Aguacate Basin

Current	Mahomita		Jiguey		Total Basin	
Land Use	(ha)	(%)	(ha)	(%)	(ha)	(%)
Crop	2,591.0	22.6	4,315.3	43.9	6,906.3	32.4
Scrub	292.5	2.5	160.6	1.6	453.1	2.1
Pasture	2,095.1	18.2	424.7	4.3	2,519.8	11.8
Coffee	5,597.0	48.7	2,997.0	30.5	8,594.0	40.3
Forestry	907.0	7.9	1,932.9	19.7	2,839.9	13.3
Total	11,482.6	100.0	9,830.4	100.0	21,313.0	100.0

Land use conflict

The land use conflict is identified by combining the potential land use with the current land use. Three categories are identified: ‘in conflict’, ‘moderate conflict’, and ‘no conflict’. Table 5.3 shows the results by each category for the basin and for each sub-basin. Figure 5.2 presents the areas with land use

Table 5.3. Land Use Conflict for Aguacate Drainage Basin

Potential Landuse	1992 Landuse	MAHOMITA SUB-BASIN					JIGUEY SUB-BASIN					TOTAL BASIN				
		Sub-basin Total (Ha)	With Conflict (Ha)	Moderate Conflict (Ha)	Not Conflict (Ha)	% of the Total	Sub-basin Total (Ha)	With Conflict (Ha)	Moderate Conflict (Ha)	Not Conflict (Ha)	% of the Total	Basin Total (Ha)	With Conflict (Ha)	Moderate Conflict (Ha)	Not Conflict (Ha)	% of the Total
AGROFORESTRY	Crop	1663.4			1663.4	14.5	593.9			593.9	6.0	2257.4			2257.4	10.6
	Scrub	1.6			1.6	0.0	0.0			0.0	0.0	1.6			1.6	0.0
	Pasture	609.1			609.1	5.3	22.0			22.0	0.2	631.1			631.1	3.0
	Coffee	2141.1			2141.1	18.6	107.8			107.8	1.1	2248.9			2248.9	10.6
	Forest	0.0			0.0	0.0	198.8			198.8	2.0	198.8			198.8	0.9
	Subtotal	4415.2	0.0	0.0	4415.2	38.5	922.5	0.0	0.0	922.5	9.4	5337.7	0.0	0.0	5337.7	25.0
	(%)	100.0	0.0	0.0	100.0		100.0	0.0	0.0	100.0		100.0	0.0	0.0	100.0	
FORESTRY	Crop	0.0	0.0			0.0	3547.2	3547.2			36.1	3547.2	3547.2			16.6
	Scrub	0.0	0.0			0.0	40.5	40.5			0.4	40.5	40.5			0.2
	Pasture	0.0	0.0			0.0	371.6	371.6			3.8	371.6	371.6			1.7
	Coffee	1183.1		1183.1		10.3	1219.0		1219.0		12.4	2402.1		2402.1		11.3
	Forest	0.0			0.0	0.0	1569.1			1569.1	16.0	1569.1			1569.1	7.4
	Subtotal	1183.1	0.0	1183.1	0.0	10.3	6747.4	3959.3	1219.0	1569.1	68.6	7930.5	3959.3	2402.1	1569.1	37.2
	(%)	100.0	0.0	100.0	0.0		100.0	58.7	18.1	23.3		100.0	49.9	30.3	19.8	
SILVOPASTORAL	Crop	0.0			0.0	0.0	152.1	152.1			1.5	152.1	152.1			0.7
	Scrub	0.0			0.0	0.0	7.7	7.7			0.1	7.7	7.7			0.0
	Pasture	0.0			0.0	0.0	31.1			31.1	0.3	31.1			31.1	0.1
	Coffee	0.0			0.0	0.0	1001.5		1001.5		10.2	1001.5		1001.5		4.7
	Forest	0.0			0.0	0.0	165.0			165.0	1.7	165.0			165.0	0.8
	Subtotal	0.0	0.0	0.0	0.0	0.0	1357.3	159.8	1001.5	196.0	13.8	1357.3	159.8	1001.5	196.0	6.4
	(%)	0.0	0.0	0.0	0.0		100.0	11.8	73.8	14.4		100.0	11.8	73.8	14.4	
PROTECTION	Crop	927.5	927.5			8.1	22.0	22.0			0.2	949.6	949.6			4.5
	Scrub	290.9	290.9			2.5	112.4	112.4			1.1	403.3	403.3			1.9
	Pasture	1486.0	1486.0			12.9	0.0	0.0			0.0	1486.0	1486.0			7.0
	Coffee	2272.9		2272.9		19.8	668.7		668.7		6.8	2941.6		2941.6		13.8
	Forest	907.0			907.0	7.9	0.0			0.0	0.0	907.0			907.0	4.3
	Subtotal	5884.4	2704.5	2272.9	907.0	51.2	803.1	134.4	668.7	0.0	8.2	6687.5	2838.9	2941.6	907.0	31.4
	(%)	100.0	46.0	38.6	15.4		100.0	18.7	83.3	0.0		100.0	42.5	44.0	13.8	
	Grand	**11482.6**	**2704.5**	**3456.0**	**5322.2**	**100.0**	**9830.4**	**4253.5**	**2889.2**	**2687.7**	**100.0**	**21313.0**	**6958.0**	**6345.1**	**8009.9**	**100.0**
	Total (%)	**100.0**	**23.6**	**30.1**	**46.4**		**100.0**	**43.3**	**29.4**	**27.3**		**100.0**	**32.6**	**29.8**	**37.6**	

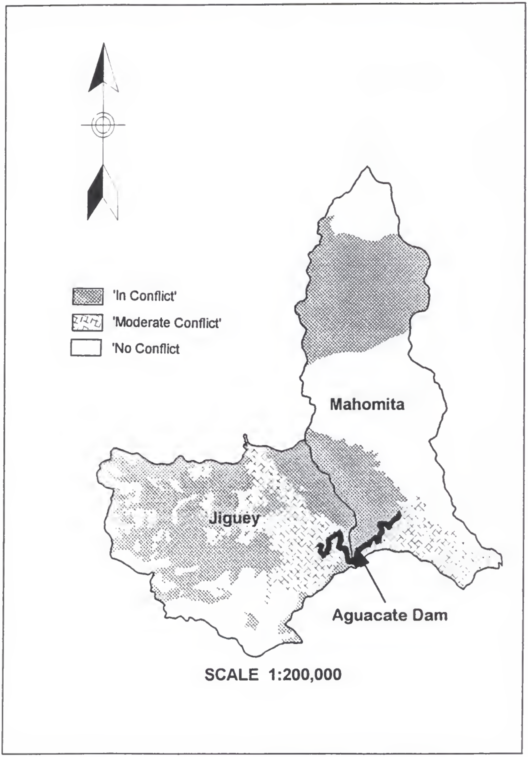


Figure 5.2 Areas with Land Use Conflict in Aguacate Basin

conflict for each sub-basin. Overall, 13,303 ha (62.4 percent) of the basin are not being used according to their capability, 6,958 ha (32.7 percent) of these are 'in conflict', and 6,345 ha (29.8 percent) are in 'moderate conflict'. Within the areas 'in conflict', 4,649 ha (21.8 percent) are being used for annual crops. While all the lands in 'moderate conflict' are planted in coffee. Only 37.6 percent of the basin (8.009 ha) presents 'no conflict' between current and potential land use. Of this 2,641 ha are dedicated to forest plantations. Total land use conflict ('in conflict' plus 'moderate conflict') for each sub-basin are: 53.7 percent (6,160 ha) in Mahomita and 72.7 percent (7,143 ha) in Jiguey. Thus, 46.3 percent (5,322 ha) for Mahomita sub-basin and 27.3 percent (2,687 ha) for Jiguey sub-basin are not in land use conflict.

Of the 6,688 ha that are recommended for protection in the total Aguacate Basin only 907 ha (13.6 percent) are currently in that land category, while 2,838 ha (percent) are in conflict, with areas planted with crop, scrub and pasture. The remaining 2,942 ha (43.9 percent) are planted with coffee thereby constituting only a moderate conflict. When the potential land use protection was analyzed in each sub-basin, the Mahomita presented the greater critical area in conflict with 2,705 ha, and 2,273 ha in moderate conflict, together accounting for 84.6 percent of the total sub-basin. Analyzing forestry as a potential land use for the complete basin, it is found that 3,959 ha (49.9 percent) are in conflict with current usage, 2,402 ha (30.3 percent) are in moderate conflict, 76.8 percent (5,178 ha) of Jiguey sub-basin is in land use conflict, while only 1,183 ha

(10.3 percent) of the Mahomita sub-basin are in moderate conflict, all in coffee. Potential silvo-pastoral land use is only designated in Jiguey sub-basin, where it represents a total area in conflict of 1,357 ha (14.5 percent).

Proposed land use

Those areas with land use in conflict were selected to implement the proposed land management plan. Three land use categories were proposed to be carry out. First, reforestation with protection forest, second, fuelwood for charcoal production, and third, coffee plantation. These proposed land uses were designed for operation in another Dominican watershed by the PRODAS project (IFAD-BID, 1993).

Table 5.4 shows a yearly plan in order to move from the current situation to the proposed land use for each sub-basin. A total of 3,850 ha (18.1 percent of the basin) in the current land use should be changed in Aguacate basin; 1,850 ha are in Mahomita and 2,000 ha are in Jiguey sub-basins.

Table 5.4 Proposed Land Use for Aguacate Basin

Year	Forest		Fuelwood		Coffee		Total
	Mahomita	Jiguey	Mahomita	Jiguey	Mahomita	Jiguey	
	..........hectares..........						
1	125	100	55	50	125	150	605
2	175	125	55	50	200	300	905
3	175	125	55	50	200	300	905
4	175	125	55	50	200	300	905
5	100	75	55	50	100	150	530
Total	750	550	275	250	825	1200	3850

The proposed land uses are planned to be gradually established over the initial five years of the project. The plan includes reforestation with *Pinus occidentalis* (6 percent of the basin or 1,300 ha), fuelwood plantation (2.6 percent , or 550 ha), and coffee cultivation (9.5 percent or 2,025 ha). The coffee cultivation begins with agriculture and gradually evolves into coffee under shade cover.

Sediment Yield

SWRRB model was run under both current land use ("without" project) and the proposed management plan ("with" project) which includes the land use changes and soil conservation practices designed with the goal of reducing sedimentation.

A summary of data requirements to run the model is provided in Table A-2. All data and model parameterization remained constant in both runs excepting those variables that change according to the project implementation, namely the retention parameter, CN (SCS curve numbers) and the C factor, values for the erosion effect of the crop and cultural practices. These variables are weighted by micro-basin each time that the project land use changes. Tables 5.5 and 5.6 present summaries, at the micro-basin level, of the CN and C values that were input into the model for each year that the project was carried out. Those micro-basins in which CN and C values changed due to project implementation are highlighted by shading. CN values show a greater decrease

Table 5.5 Weighted CN Values by Micro-basins for Aguacate Basin

JIGUEY							MAHOMITA						
ID	YEAR						ID	YEAR					
#	0	1	2	3	4	5	#	0	1	2	3	4	5
41	70	70	70	70	70	70	51	66	66	66	66	66	66
42	68	68	68	68	68	68	52	68	68	68	68	68	68
43	68	68	68	68	68	68	53	58	58	58	58	58	58
44	72	72	72	71	70	70	54	76	72	69	66	66	66
45	69	69	69	69	69	69	55	74	72	70	68	66	66
46	77	76	74	72	70	70	56	76	76	76	75	74	73
							57	75	75	74	73	71	70
							58	78	78	78	78	78	78

Source: Tables; A-3, A-4, A-5 and A-6.

Table 5.6 Weighted C Values by Micro-basins for Aguacate Basin

JIGUEY							MAHOMITA						
ID	YEAR						ID	YEAR					
#	0	1	2	3	4	5	#	0	1	2	3	4	5
41	.043	.043	.043	.043	.043	.043	51	.045	.045	.045	.045	.045	.045
42	.045	.045	.045	.045	.045	.045	52	.045	.045	.045	.045	.045	.045
43	.044	.044	.044	.044	.044	.044	53	.045	.045	.045	.045	.045	.045
44	.152	.152	.146	.128	.114	.114	54	.245	.165	.112	.073	.073	.073
45	.078	.078	.078	.078	.078	.078	55	.194	.154	.120	.079	.055	.055
46	.279	.254	.219	.194	.165	.144	56	.104	.104	.095	.085	.073	.069
							57	.144	.144	.129	.113	.081	.052
							58	.031	.031	.031	.031	.031	.031

Source: Tables; A-7, A-8, A-9 and A-10.

in micro-basins 46, 55 and 54 losing 7, 8 and 10 units respectively as the project is carried out. For C values the same micro-basins show similar trend with a decreasing of 0.172, 0.139 and 0.135 decimal units. Detailed calculations for CN are presented in Tables A-3, A-4, A-5 and A-6 and for C parameters are shown in Tables A-7, A-8, A-9 and A-10.

Sediment yields "without" project scenario.

Sediment yields estimated "without" the project for each micro-basin by sub-basin are presented in Table 5.7. In the Jiguey sub-basin, the micro-basins 41, 42, 43 and 45 present the lowest sediment yields (between 1.5 and 4.1 t/ha.yr). The principal current land use for these micro-basins is coffee (see Figure 5.3a). The percentage of permanent crops that cover these micro-basins is between 75 and 100 percent. On the other hand, micro-basins 44 and 46 present high sediment yields of 13.4 and 64.8 t/ha.yr, respectively.

Table 5.7. Average Annual Sediment Yield Without Project by Micro-basin

JIGUEY		MAHOMITA	
Micro-basin ID#	Sediments yield t/ha.yr	Micro-basin ID#	Sediment Yield t/ha.yr
41	4.1	51	0.8
42	2.2	52	4.5
43	1.5	53	2.3
44	13.4	54	75.4
45	1.9	55	55.0
46	64.8	56	8.4
		57	12.6
		58	5. 2

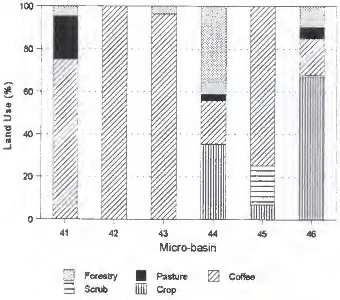


Figure 5.3a Current Land Use for Jiguey Sub-basin

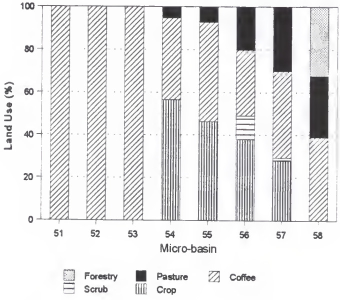


Figure 5.3b Current Land Use for Mahomita Sub-basin

Micro-basin 46 contains a high percentage (67 percent) of crop coverages. While micro-basin 44 contains various uses including forest, crops coffee (41, 35 and 20 percent respectively).

Similar associations between high sediment yields and land uses can be identified in the Mahomita sub-basin. Micro-basins 51, 52, 53 and 58 show the lowest sediment yield values (0.8, 4.5, 2.3 and 5.2 t/ha.yr, respectively); the first three of which are planted with coffee and the last with 71 percent of perennial crops (coffee and forest). By contrast, micro-basins 54, 55, 56 and 57 present the highest percentage of annual crops with 56.5, 40.6, 42.7 and 27.9 percent respectively (Figure 5.3b.). Sediment yields for these sub-basins are; 75.4, 55, 8.4 and 12.6 t/ha.yr. Overall it, is observed throughout the Aguacate basin that those micro-basins with the largest areas of annual agricultural crops present the highest sediment yields. Conversely, those micro-basins with the lowest values of sediment yield are those with the smallest areas of annual crops and the largest areas with permanent crops.

Sediment yields "with" project scenario.

Sediment yield results from the simulation "without" project management are used to identify the most critical micro-basins, which then are considered as priorities for implementation of land use change. Those micro-basins containing areas in which the current land use are dominantly crops, but theirs potential land capability are forestry and/or protections, are considered first to change the land use under the project implementation.

Figure 5.4 shows the micro-basins selected for initial modification. In the Jiguey sub-basin two micro-basins with highest sediment yield, 44 and 46, were selected. Micro-basin 46 represents 31% of the Jiguey sub-basin and 1,650 ha of the current land use a 36.4% of its area would be proposed to change. Ten percent (350 ha) of micro-basin 44 are also proposed to change. Together these two sub-basins contain 2,000 ha (20.4%) of the land in the entire sub-basin that is proposed to converted to new land use.

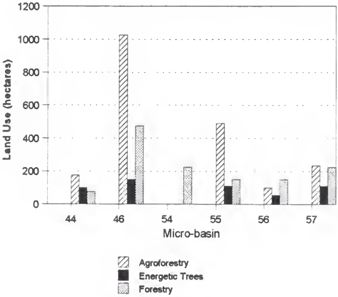


Figure 5.4 Proposed Land Use Change by Micro-basin in Aguacate Basin

Four micro-basins are chosen for change from current land use in the Mahomita sub-basin. The most critical ones, with the highest erosion risk, are number's 54 and 55. Proposed land use change for these two micro-basins total

150 hectares (40.3%) for the first one and 800 hectares (37.4%) for the second one. The remaining two, micro-basins 56 and 57, would experience 305 and 570 ha, (14 and 26.5%) of change respectively. A total of 1850 ha (16.1%) is proposed for change for the Mahomita sub-basin.

Micro-basins sediment yields. The SWRRB model is rerun after making necessary changes to parameters describing land use and conservation practice. Five separate runs (one for each proposed land use change) are completed and the results of average annual sediment yields in each micro-basin are computed and are shown in Table 5.8. Micro-basins in which project changes were carried out are highlighted by shaded rows. A trend of decreasing sediment yield is observed in each of the six micro-basins receiving project management throughout the period of the project. A comparison of the sediment

Table 5.8 Average Annual Sediment Yield With Project by Micro-basin

JIGUEY						MAHOMITA					
ID #	1st	2nd	3rd	4th	5th	ID #	1st	2nd	3rd	4th	5th
			t/ha						t/ha		
41	4.1	4.1	4.1	4.1	4.1	51	0.8	0.8	0.8	0.8	0.8
42	2.2	2.2	2.2	2.2	2.2	52	4.5	4.5	4.5	4.5	4.5
43	1.5	1.5	1.5	1.5	1.5	53	2.3	2.3	2.3	2.3	0.8
44	12.7	12.7	10.6	8.1	8.0	54	29.2	13.8	5.6	5.6	5.3
45	1.9	1.9	1.9	1.9	1.9	55	33.9	22.9	12.2	8.4	8.1
46	48.6	38.1	32.7	23.8	20.3	56	8.4	7.2	5.4	4.1	3.2
						57	12.3	8.4	6.1	2.8	1.4
						58	5.2	5.2	5.2	5.2	5. 2

yields, by micro-basins, for the without project, to last year with the project, reveals that the largest reductions in sediment yields are found in units 54, 55 and 46 with 70.1, 46.9 and 44.5 t/ha (difference between the sediment yield "without" project, Table 5.7, and the sediment yield of last year "with" project, Table 5.8), respectively. The smallest reduction in sediment yields are found in micro-basins 56, 44 and 57, with 5.2, 5.4 and 10.9 t/ha respectively.

Figure 5.5 shows the comparison of the total sediment yield (in ton) between, the "without" project (initial sediment yield) and "with" project (last year of the project). For Jiguey sub-basin, the greatest reduction occurs in micro-basin 46, with 201,783 tons (from 293,833 to 92,049), while micro-basin 44 diminishes only by 18,958 tons (from 47,044 to 28,086). Micro-basin 46 accounts for 91.4 percent of the reduction in sediment yield although it only occupies 46.1 percent of the Jiguey sub-basin area. For the complete Jiguey sub-basin, "without" project, 340,877 tons are yields and "with" project, the sediment yields reach 120,136 tons, a 64.7 percent reduction (220,741). For Mahomita sub-basin, "without" project, the sediment yields for the four component micro-basins (54, 55, 56 and 57) are 190,804 tons. When the project management is completed, the sediment yields reach 29,159 tons, an 84.6 percent reduction (161,645 tons). Micro-basin 55 occupies 18.6 percent of the sub-basin area and accounts for 61.9 percent (117,687 tons) prior to project implementation. An 100, 355 ton (62.1% of the total reduction) decrease in yield is anticipated for this micro-basin at the end of the project. By contrast, the combined reduction among the remaining three micro-basins (54, 56 and 57) is only 61,290 tons (37.9 % of the total reduction).

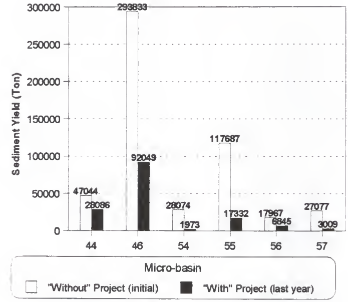


Figure 5.5 Comparison of Sediment Yield "With" and "Without" Project by Micro-basin

Basin sediment yields. Basin sediment yields are the total sediment yield arriving at the sub-basins outlet at the Aguacate reservoir. Results for Jiguey and Mahomita sub-basins are displayed in Figure 5.6. Before the project, sediment yield for Jiguey sub-basin is greater than Mahomita sub-basin, 28.9 and 15.7 t/ha.yr respectively. Gradual deliveries in sediment yields are observed throughout the project period, ultimately reaching minima of 11.14 and 3.57 t/ha.yr respectively. These represent a 61.5 percent decrease in sediment yield for Jiguey and a 77.3 percent decreases in the Mahomita. This suggests that the projected management scheme would dimish sediment yield by 17.8 (61.5 percent) and 12.2 (77.3 percent) t/ha for Jiguey and Mahomita respectively.

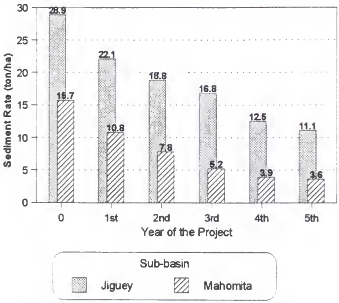


Figure 5.6 Sediment Rate by Sub-basin

Sediment Delivery to the Reservoir.

Sediment delivered to Aguacate reservoir, and the impact of a cumulative deposition of sediment on the lifetime of the hydroelectric facility are estimated. Sediment delivered and trapped sediments in cubic meters during the project implementation are shown in Table 5.9. This table summarizes the data presented in Table A-11 which details calculations of sedimentation rates for each year and sub-basin. The first three years of the project, variation in sediment yields are not estimated due to that the effects of land use and conservation practices are not stable at the first stage of the project. Thus, the proposed land use established in Year 1 of the project affects the sediment yields at the beginning of the Year 4. The same procedure is applied for the following project years, a proposed land use of project Year 2 corresponds to Year 5, and so on. Initial sediment delivered to the reservoir is 387,713 m^3; 61.2 percent (237,165 m^3) of these sediments are contributed by Jiguey sub-basin and the remaining 38.8 percent (150,548 m^3) are given by Mahomita sub-basin. For the Year 4 the annual rate shows a 26.6 percent decrease in the initial sediment delivery. For year; 5, 6 and 7 , the sediment delivery decreases by 19.9, 18.1 and 25.8 percent, respectively. From year 8 to year 50, with project management the rate decreases by 10.7 percent. This is 125,399 m^3/yr, which is the lowest level of sedimentation during the project implementation. Therefore, it was with project implementation would reduce the reservoir sedimentation by almost 68 percent. Veloz et al. (1985) found comparable results for Valdesia reservoir. They observed that complete adherence to the project management in Nizao watershed would reduce the reservoir sedimentation rate by 80 percent.

The last column in Table 5.9 shows the volume of sediments trapped in the Aguacate reservoir and is calculated using the Brune method (1953). Reservoir trap efficiency is defined as the ability of the reservoir to trap and retain sediment (Chow, 1964). Various empirical methods to predict the proportion of incoming sediment that is retained in the reservoir have been developed. According to Mahmood (1989), Brune's curve is most popular in practice mainly because it uses a rather simple and readily available predictor. The independent parameter in this method is the volume ratio of reservoir storage to annual water inflow and the dependent variable is trap efficiency. The estimate trap efficiency for Aguacate Basin is 78 percent (see Brune's curve Figure A-2).

Table 5.9 Sedimentation Yields and Trapped Sediments for Aguacate Reservoir

Project	Sediment Delivered			Trapped
Year	Jiguey	Mahomita	Total	Sediment
	....................m^3/yr....................			
1-3	237,165	150,548	387,713	302,416
4	181,101	103,635	284,736	222,094
5	153,897	74,939	228,836	178,492
6	137,743	49,803	187,546	146,286
7	102,576	37,757	140,333	109,460
8-50	91,231	34,169	125,399	97,811

Source: Table A-11.

The predicted sediment yields are tested comparing measured values from a bathymetric study performed in the Valdesia reservoir (Espinal, 1992). The results estimate an average net sediment accumulation of 2,050 m^3/km^2/yr. Valdesia reservoir is within the Nizao watershed, and downstream from

Aguacate reservoir. The study was carried out a year before construction was completed on the Aguacate dam. It covers a span of twelve years (1979 to 1991). Aguacate reservoir sedimentation rate is 30.7 percent less than that calculated for the Valdesia reservoir. A similar bathymetric study was carried out by Espinal (1992) in the Sabaneta reservoir, also located in the southern portions of the Central Cordillera of Dominican Republic. He found that an average of 2,106 $m^3/km^2/yr$ was entering the reservoir 11 years after the beginning of operation of the dam. This rate is 32.6 percent greater than the computed rate in the Aguacate reservoir, but several factors can explain these differences such as, land use, topography and hydrologic conditions. Although, additional research should be carried out, the model could initially be validated using these measured values.

Lifespan of Aguacate Dam

The life of the dam is defined as the number of years of operation before the useful volume of the reservoir becomes filled with sediment.

Aguacate dam has a useful storage volume of 2.84 million cubic meters which is equivalent to a level of 324 masl. Figure 5.7 shows the accumulation of trapped sediments in the reservoir both "with" and "without" the project assuming that there will be no attempt to dredge or remove sediment from the reservoir (see Table A-12 for detailed information). If the projected management is not carried out the reservoir's useful storage capacity would be filled by the year 2001, that is, only nine years after that the dam commenced its operations.

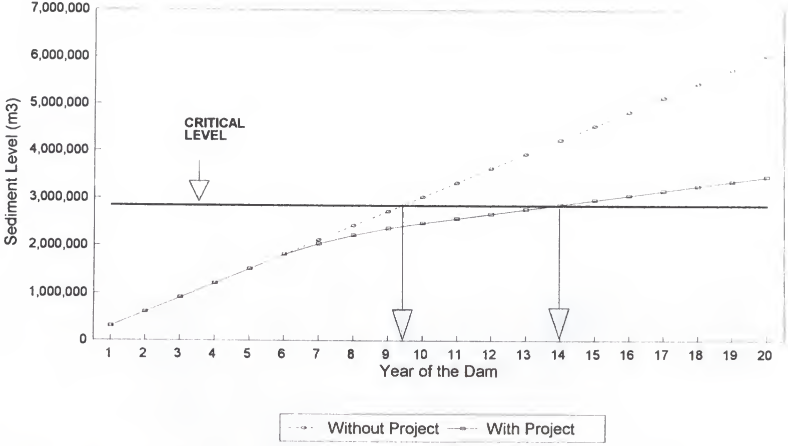


Figure 5.7 Lifetime of Aguacate Reservoir "Without" and "With" Project Management

The expected lifespan of the reservoir is extended by over 50%, until year 2006, when project management is carried out.

Knowing the small storage capacity of the dam relative to the sediment yields by the basin, the dam designer presented a model to avoid the limited lifespan of the Aguacate dam, which involved methods of removing sediment deposits from in front of the power intake. The study was performed by three consulting engineering firms; EPSA-LABCO, Benham-Holway Power Group and Dames and Moore, and a simulation model was run out by the Engineering Research Center at Colorado State University. Ruff and Brisbane (1991) explain the way in which the model program was developed to evaluate the scour and sediment transport potential in the forebay of the power intake; produced the flow conditions entering the power intake and the scour resulting from spillway operations. If the scour can remove sediment from the forebay of the power intake, dredging or mechanical cleaning will be reduced or eliminated. Tests were performed both with constant discharges and with a series of increasing and decreasing discharges to simulate a flood hydrograph. The results showed that any individual gate or any combination of gates diminishes sediment accumulation. The exact operating procedures employed depend upon the flow patterns, but it found that the first three to five intake bays nearest the spillways were cleared of sediment for all flows greater than 2,000 cms. According to these results, the dam could be operating without problem (depending on the flows). Some dredging of the sediments in the reservoir may be required.

Gomez-Achecar (1995), EPSA-LABCO Technical Director agrees that part of sediments accumulated in the tail of the reservoir should be dredged. To keep the dam operating, sediments must never reach the power intake level of 322.6 masl, as damage then would occur to the intake, penstock, or turbines, and could reduce the inflow and power generation. To prevent clogging of the power intake by sediment deposition it was decided that when the sediment level reached 322 masl., the spillway gates are to be opened to draw out sediments. It is assumed that annually a maximum of 300,000 m^3 of sediments are drawn out which translates to a drop 1 meter in the height of the reservoir level to 321 masl. according to Castellanos and Iturbides (1993). This level, "without" project, will be reached eight years after the dam starts its operations.

If these 300,000 m^3 of sediments are withdrawn annually through the spillway gate system, removing sediments by dredging will not be necessary. Depending on how efficiently the spillway gate system works, it may not be necessary to remove all the sediments from in front of the power intake. Ten different levels of efficiency are analyzed employing percentages from 0 to 100, increasing by 10 each time of the 300,000 m^3 estimate to be drawn out by the spillway system.

Figures 5.8 and 5.9 show the sediment levels depending upon the percentages of sediments that need to be drawn out by the spillway gates "without" and "with" the project management (see Tables A-13 and A-14 for

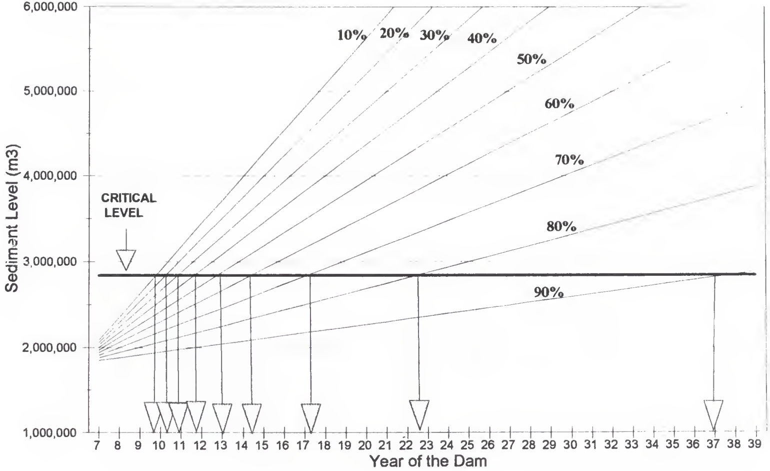


Figure 5.8. Sediments Drawn by the Spillway and Reservoir Lifetime "Without" Project

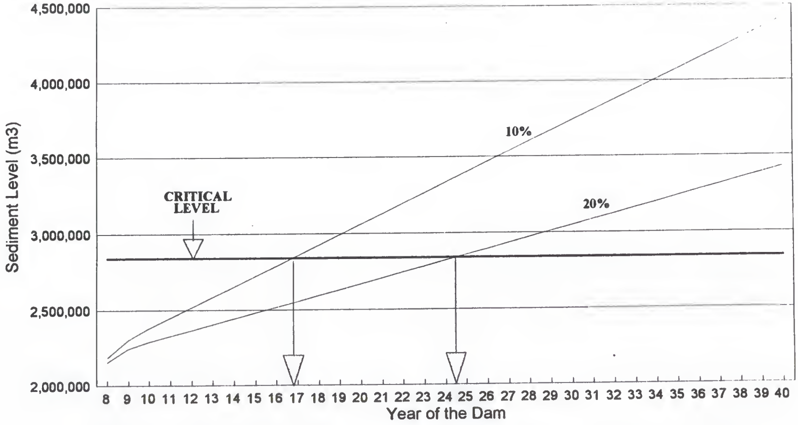


Figure 5.9. Sediments Drawn by the Spillway Gates and Reservoir Lifetime "With" Project

details). Arrows in both figures highlight the year in which the dam would become filled. Without the project, when 100 percent of sediments are drawn out the dam is never filled, but under the other nine scenarios of efficiency varying from 10 to 90 percent the dam is economic life would cease from 9 to 37 years. If the proposed management plan is implemented, only under the scenarios of 10 and 20 percent of efficiency the dam is economic life would cease in 17 and 24 years respectively. The dam could stay operating in any of the remaining scenarios, as the sediments would never reach the power intake when the effects of spillway gates are combined with the anticipated sediment reductions.

Benefit-Cost Analysis

Several steps are considered to evaluate the overall benefits from the reduction of sediment, and the resultant economic impacts of watershed management scenarios in the basin. First, sedimentation rates were estimated for each sub-basin. Then, total sediment delivery to Aguacate reservoir, and the impact of a cumulative sediment deposition on the lifetime of the hydroelectric facility are determined. This sequence is presented under the two scenarios of "with" and "without" a watershed management project. Lastly, the economic net benefits of land management alternatives on sediment reduction are evaluated using benefit-cost analysis.

The following discussion presents an economic analysis of the benefits and costs to carry out the proposed watershed management program in the

Aguacate basin. Detailed computations appear in the appropriate Appendices.

Quantification of Benefits and Costs

The benefits derived with watershed management are viewed as losses that have been avoided in the design and operation of the hydropower storage reservoir. Once the physical losses have been quantified, the next step is to assign them some monetary value. Any reduction in the designed volume is considered as a loss attributable to sedimentation. Using the computed unit benefit values, the values of the loss due to the reduction of reservoir storage are determined. Briones (1986) completed similar calculations in the estimation of benefits obtained with watershed management in the Philippines in terms of flood control, irrigation, and hydropower storage capacity. To illustrate the benefits of this proposed scheme, the "with" and "without" watershed management conditions are compared. The determination of benefits of "losses avoided" in the storage reservoir requires the calculation of the economic value of 1 m^3 of storage capacity in Aguacate reservoir. This was completed using the approach outlined by IFAD (1993) in four other Dominican reservoirs. Jorge (1993) also estimated the value of storage capacity for Valdesia reservoir in the lower part of Nizao watershed.

The downstream value of dam operation in Year t can be written as; $P_v (V_0 - V_t)$, where P_v is the annual economic value generated by 1 m^3 of storage space in the reservoir, V_0 the initial useful volume of the reservoir, and V_t the volume of accumulated sedimentation. The economic value of space in the reservoir is determined by the electrical power generation capacity.

The net value of the dam is equal to the benefits obtained with its operation over the alternative power source that would replace it in its absence, in this case oil-fired generation. The value of electrical power, generated from the dam operation, is based on the cost of producing the same electricity with the alternative source used in the country. According to IFAD (1993), the benefit of storage capacity is that it allows the transformation of a regular flow of water, and thus the possibility of producing base electricity in a continuous way, into a discontinuous release and therefore the concentrated production of electricity to meet peak demands. The value of the capacity itself is measured by the difference between the value of the peak electricity and the base electricity. Thus, the alternative to hydroelectricity is electricity produced from petroleum. As petroleum is imported, the cost of petroleum-based energy depends on the exchange rate. This alternate method of production costs US$ 0.14/KWh. Base electricity can be produced at the lower cost of US$0.05/KWh in hydroelectric plants. Therefore, the value of the dam capacity is this difference in cost, or US$0.09/KWh. The opportunity cost of producing electricity translates to DR$1.158/KWh at the current exchange rate of DR$12.87 (Banco Central,1995).

Therefore, the derived economic value of 1 m^3 of space in the reservoir given the above calculated cost difference, an annual energy potential of 208 GWH, and the useful reservoir capacity volume of 2.84 $10^{\wedge 6} m^3$ of the Aguacate reservoir, is DR$84.81.

Figure 5.10 shows the anticipated benefits obtained as a function of avoided sedimentation should the project be carried out. The economic value of the sedimentation avoided is calculated as the difference between annual sediment delivery (in m^3) "with" and "without" the project, multiplied by the value of a cubic meter of storage capacity. Under the proposed management scheme, the sedimentation rates would not differ during the first three years (Year 6 of the dam) because of a delay in the response of the basin to changes in land use, thus the "avoided sediments" in this period are zero and no benefits are accounted. The net benefit due to avoided sediments "with" the project begin to accumulate at Year 4 of the project (Year 7 of the dam), and increase through year 4 to 8. After Year 8 and the cessation of the project, the benefits remain constant. Details are presented in Table A-15.

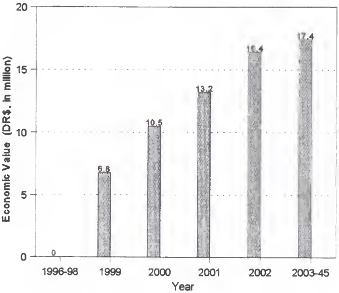


Figure 5.10 Economic Value of the Sediments Avoided

Table 5.10 presents a summary of anticipated benefits estimated during a fifty year period of project implementation. Upstream benefits of planting the coffee system and fuelwood plantations are presented in detail in Tables A-16 and A-17, respectively. Revenues from production are included separately for each activity. No benefits accrue from forest plantations; they are solely considered for soil protection.

Table 5.10. Summarized Total Undiscounted Benefits "With" Project

Purpose	Benefits (DR$)
Economic Value of Avoided Sediments	793,359,836.67
Fuelwood Plantations	24,108,000.00
Coffee System	2,026,253,650.00
Total Benefits	2,843,721,486.67

Sources: Tables A-16 and A-17.

Total costs of project implementation include: the cost of the watershed management project, the cost of the proposed land use changes and the operating cost of the hydroelectric power plant. Table 5.11 summarizes these total costs, estimated during the fifty years of the project implementation. Detailed calculations for each category are presented through Tables A-16 to A-19. The watershed management project costs include those costs related to conservation practices, engineering, basic studies, land acquisition, technical training, external assistance, extension services and administrative costs. The last two categories are estimated for the fifty year project, while the others are all completed during the initial five years of the project. Costs of establishing the proposed land uses are detailed for each category separately. To estimate the operating costs of the hydroelectric plant, data of its first two years of operations are used (CDE, 1995). Operating cost and maintenance are assumed to increase during the fifty years of the project. The estimated yearly increased cost is 2 percent.

Table 5.11. Summarized Total Undiscounted Costs "With" Project Management

Purpose	Costs (DR$)
Operation and Maintenance	201,575,042.34
Watershed Project Management	37,060,000.00
Extension Services and Administration	54,000,000.00
Protection Forestry	12.166,500.00
Fueldwood Plantations	13,321,875.00
Coffee System	1,588,452,475.00
Total Costs	1,906,575,892.34

Sources: Tables A-16, A-17, A-18 and A-19.

The Undiscounted net benefits for the coffee system is 47 percent of the project. The recommended coffee system stars with agriculture and gradually evolves into coffee under tree cover. Agriculture crops in the first three years helps reduce the costs of financing the transition to coffee.

Net Present Value

The downstream benefit of the reservoir is computed as the difference between net present value of the stream of the revenues and the net present value of the costs. The net present value (NPV) is calculated under differing discount rates from 4 to 18 percent. Figure 5.11 shows expected NPV under each discount rate. At the highest discount rate of 18 percent, negative NPV of DR$1.96 million is reached, while that at the lowest a discount rate of 4 percent the NPV rises to DR$309 million.

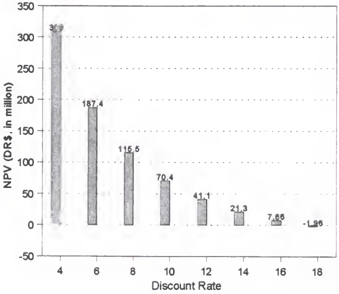


Figure 5.11 Mean Net Present Values

Comparisons of net benefits per year after project implementation at varying different discount rates are shown in Figure 5.12 (see Table A-20). The net benefits for the first five years of the project are all negative. Positive values

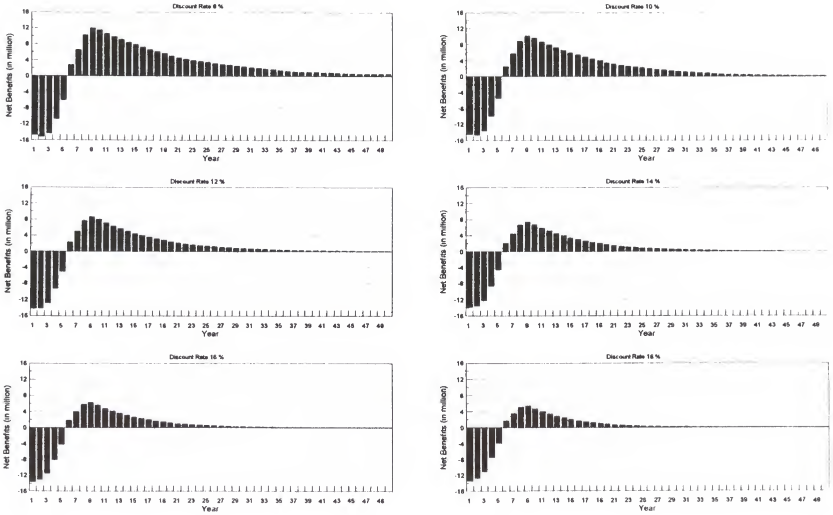


Figure 5.12. Net Benefit Per Year By Discount Rate

star to appear in Year 6 and end with the project, although greatly reduced benefits are found at the end of the project. The greatest benefit values, and the longest persistence are found at the lowest discount rate.

The net present values (NPVs) for the project, using the varying discount rates are at least DR$ 7.66 million (16% discount rate). This measure provides an indication of the present values of the net benefits due to the project, and suggests that the project can be profitable at that discount rate.

Benefit-Cost Ratio

The benefit-cost ratios for the proposed plan were calculated using the same discount rates used with the net present values. Figure 5.13 shows the comparison between benefits and costs estimated at different discount rates; data are presented in Table A-21. Using this information, a benefit-cost ratio is calculated. Only at a 18 percent discount rate is the benefit-cost ratio less than 1, the costs are greater than the benefits by DR$1.96 million. At 4 percent of discount rate is the highest benefit-cost ratio with 1.4, follows by; 1.32, 1.27, 1.2 1.14, 1.09, and 1.04 at 6, 8,10, 12, 14, and 16 percent of discount rates. Since the values were greater than 1, the proposed watershed management plan is found to be justified in economic terms.

Both measures, the NPV and the benefit-cost ratio, showed that the watershed management project represents an economically efficient use of resources, given the discount rate equal to or less than 16 percent.

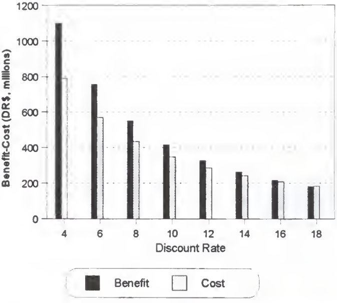


Figure 5.13 Benefit and Cost by Discount Rates

The project internal rate of return (IRR) is 17.5 percent. The project can be profitable at real interest rates below the internal rate of return (IRR). According to IAFD (1993) in the Dominican Republic the nominal interest rate for lending commercial banks was 27 percent and the inflation below 9 percent. This indicates a real rate of interest of around 18 percent. Perez Luna (1995) agrees that currently the real rate of interest have decreased around 15 percent. If is considered that the real social discount rates are often in the range of 3 to 8 percent the project is highly recommended. For countries like the Dominican Republic with low per capita income, development banks, charge interest rates in the range of 4 to 8.

CHAPTER 6
SUMMARY AND CONCLUSIONS

The Dominican Republic has neglected the effects of upstream agricultural land use on downstream reservoirs in most of its water resources projects. The impacts of sedimentation can seriously decrease the effectiveness of reservoirs and affect the balance of benefits and costs.

The Simulator for Water Resources in Rural Basins (SWRRB) computer-based deterministic model was used to predict erosion and sediment yields in the ungaged Aguacate Basin in Nizao watershed, Dominican Republic. This hydrological model estimates changes in sedimentation rates under different land use scenarios. To integrate these predictions on physical quantities of erosion and sediment yields into an economic framework, a benefit-cost analysis is included. This case study evaluates two scenarios, no watershed management program with a constant sedimentation rates, and a watershed management program with a decrease in sedimentation rates. The benefits are considered a direct function of the volume of the storage capacity of the hydroelectric dam. All reductions in storage volume are attributed to sedimentation.

In Aguacate sub-basin more than 62 percent of the lands in the basin are not being used according to their capability, only 13.3 percent are covered in natural forest, while one third are in agricultural crops. Results of this study indicate that, appropriate land use changes have significant effects in controlling upstream erosion and therefore reservoir sedimentation. It is observed that micro-basins with largest areas of annual crops present the higher sediment yields than those areas with smallest areas of annual crops. For example, micro-basins with 67 and 56 percent of annual crops present high sediment yield values of 64.8 and 75.4 t/ha.yr, respectively. Conversely, micro-basins without lands in annual crops present low sediment yield values of 0.8 and 1.5 t/ha.yr. The sediment yield predicted results, using land use changes for those critical areas with severe erosion risk, showed that sediment delivered to the reservoir decreases 67.7 percent from 387,713 m^3/yr "without" project to 125,399 m^3/yr "with project. More than 50 percent extend the expected lifespan of the reservoir when project management is implemented. Model validity is accounted when the results are compared with observed-yield data from bathymetry of the study region and, other studies in similar locations.

The economic analysis results suggest that "with" project management scenario is an economically attractive control strategy for reducing sediment damages. The net present values (NPV) and the benefit-cost ratio show that the watershed management project represents an economically efficient use of resources, given the discount rate equal to or less than 16 percent.

In summary, achieving watershed management project in Aguacate basin would generate significant erosion and sediment reduction benefits. The study reaffirms the effectiveness of applying appropriate land uses in combination with conservation practices in those areas in land use conflict.

The following conclusions are drawn from the study: First, sediment accumulation decreases the useful storage volume, and, if not controlled, sediments will eventually completely displace the useful storage capacity; second, reservoir sedimentation can be eventually controlled by limiting soil erosion in upstream areas using land use project management; and third, the economic benefits of hydroelectric development can be lost because of reservoir sedimentation without a management project.

In developing countries, like the Dominican Republic, rarely is a watershed protection plan implemented along with the construction of the dam. In order to avoid a major reservoir sedimentation problem, it is recommended that a watershed management project be developed previous to the dam construction.

Accomplishing watershed management is an important consideration for sustainability of water development projects, but this is not an easy attainment. It would require simultaneous achievement of many tasks, among which are reforestation and land uses with conservation practices. Land use practices are generally very sensitive matters in most of the developing countries. Sometimes, due to political conditions and conflict of interest, it is difficult to develop and implement a rational land use policy. Additionally, since watershed projects cover large areas, ensuring appropriate land use practices over the entire catchment areas may not be a viable process.

Although, reforestation for degraded lands requires a considerable capital investment in initial project years, with no direct financial return to the investors, the governments of the developing countries would have to play the main role in reforestation, and/or subsidize private efforts substantially.

Watershed management should not be viewed from the narrow viewpoint of benefits to water projects alone; it should be considered to be essential for soil and water conservation, which in the long run will increase the prospect of self-reliance of developing nations in terms of food and energy. Watershed management in this holistic perspective should be considered to be a priority activity.

Problems regarding the availability and reliability of the data limit the study results. The climatological record for Valdesia Station, which is located downstream in the lower Nizao watershed and outside the Aguacate study region, was used to provide input data for the SWRRB model runs. This station was the closest source of precipitation and temperature data with a sufficient period of continuous records. Model validation of the sedimentation rates relied on the results of -bathymetric surveys of sediment deposition from the entire Nizao watershed in Valdesia Reservoir. The 30.7 percent lower sedimentation results in this study than the measurements at the reservoir could be due to the fact that Aguacate basin represents 25 percent of the sediment source area.

Some uncertainty associated with assumptions in the study could be reduced significantly with additional field work. Nevertheless, additional study ought to show that computer hydrological model could be a necessary tool for a better approach to set reservoir sedimentation in developing countries. The benefit-costs analysis data estimates in this study were developed from secondary sources. It would be proper in this benefit-cost analysis to subtract the loss in net revenues from existing land uses displaced by the new land management program. Specific information on the net revenues for these activities is not available. With the move under the land management program to improve coffee production, it is expected that the increase in net revenues from more effective coffee production will far out weight the loss of net revenues from the previous land uses.

Additional socioeconomic surveys are recommended to get detailed information related to costs and benefits of specific crops and management practices.

APPENDIX

Table A-1. Summary of Monthly and Yearly Rainfall in Valdesia

						MONTH							
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
							milimeter						
1973	135.0	90.6	27.1	22.1	59.8	45.5	78.5	182.1	87.8	304.3	36.2	57.8	1,126.8
1974	20.0	64.6	28.4	163.0	189.1	96.2	59.3	161.6	275.6	99.3	132.4	9.8	1,299.3
1975	15.5	36.0	52.5	59.0	68.5	49.5	53.0	91.0	319.0	129.6	79.5	169.0	1,122.1
1976	45.0	62.0	60.0	59.0	87.0	348.0	53.0	155.0	201.0	213.1	72.0	71.0	1,426.1
1977	31.0	16.6	12.0	49.0	462.5	87.0	59.0	254.5	144.5	185.0	191.0	127.5	1,619.6
1978	38.0	41.5	255.7	140.5	252.0	153.7	44.5	255.5	110.0	261.5	127.4	31.9	1,712.2
1979	7.1	36.3	80.5	70.9	259.9	552.9	245.3	325.2	519.9	270.8	121.7	23.2	2,513.7
1980	50.8	37.9	34.8	263.8	100.3	57.3	143.3	253.4	180.2	102.2	103.5	62.2	1,389.7
1981	53.1	61.8	38.5	34.3	796.5	420.2	179.6	203.2	94.6	154.8	110.3	82.3	2,229.2
1982	76.0	79.4	24.1	116.5	309.5	369.9	205.7	88.4	199.4	137.6	111.9	49.6	1,768.0
1983	21.0	7.7	148.6	180.5	370.4	439.1	108.6	306.7	196.4	142.0	53.0	47.2	2,021.2
1984	87.6	85.8	37.9	40.1	129.2	343.3	328.5	248.0	289.2	145.1	63.6	42.8	1,841.1
1985	40.5	83.6	113.8	49.9	137.4	81.2	131.7	249.9	560.2	436.7	319.9	25.3	2,230.1
1986	90.4	42.9	136.6	220.6	378.2	387.9	57.4	205.7	83.6	175.3	152.8	58.3	1,989.7
1987	38.7	105.4	27.3	105.8	170.6	326.9	118.8	59.8	280.4	142.9	95.9	393.6	1,866.1
1988	54.6	57.0	57.1	102.4	123.1	314.5	165.9	560.6	303.4	192.2	235.7	38.9	2,205.4
1989	78.9	131.9	315.1	129.6	105.4	30.6	81.7	151.9	127.6	123.0	81.9	9.4	1,367.0
1990	158.4	47.5	47.9	78.6	39.9	211.1	149.4	39.4	87.6	530.7	191.8	40.3	1,622.6
1991	12.6	29.0	57.6	81.1	466.0	48.7	73.0	75.1	210.5	140.6	146.5	25.0	1,365.7
1992	154.7	68.1	73.1	117.2	227.8	262.2	240.7	259.0	166.7	7.8	370.4	97.4	2,045.1
Mean	60.4	59.3	81.4	104.2	236.7	231.3	128.8	206.3	221.9	194.7	139.9	73.1	1,738.0
St Dev	45.6	30.7	79.5	64.4	186.2	163.6	78.9	118.1	132.9	119.8	86.3	85.0	

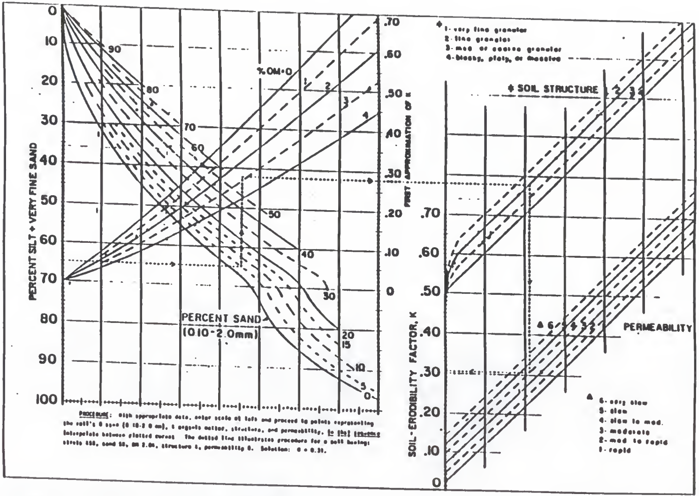
Source: Modified from Division de Hidrologia (INDHRI)

Table A-2. Model Input Requirements

INPUT AT EACH READ STATEMENT	(VARIABLES) DEFINITIONS	UNITS	TYPICAL RANGE
1. Title	(TITLE)		
2. Program Control Codes	(NBYR) Number of years of runoff simulation		1-100
	(IYR) Beginning year of runoff simulation		1-2000
	(LU) Number of sub-areas in basin		1-5
	(NS) Number of soil layers		1-10
	(IPD) Print code: 0=monthly, 1=daily, 2=yearly		0-2
	(NSIM) Code for rainfall input: 1=measured single, 2=simulated single, 3=measured multiple, 4=simulated multiple		1-4
	(MSIM) Code for temperature input: 1=measured 0-2 maximum and minimum temperature, 2=simulated single temperature for entire basin, 3=simulated maximum and minimum temperature for each sub-basin		
	(IGN) Number of times random number generator cycles before simulation begins		0-100
3. General Data	(DA) Basin area	Km^2	0.1-5000
	(P2) Rainfall correction factor		0.5-1.5
	(TP5) TP-40 10yr frequency 0.5h rainfall	mm	5.0-150
	(TP6) TP-40 10yr frequency 6.0h rainfall	mm	25-200
	(TP24) Number years record max 0.5h rain		5-100
	(YLT) Latitude of Watershed	deg	-90-90
	(BRT) Basin lag time	days	0-100
	(FFC) Fraction of field capacity-initial water storage		0-1
4. Sub-basin Coordinates	(XIJ) X-centroid coordinates of sub-basins	km	0-200
	(XIJ) Y-coordinates of sub-basins	km	0-200
5. Temperature	(OBMX) Ave. monthly max. air temperature	°C	-10-42
	(OBMN) Ave. monthly min. air temperature	°C	-30-30
	(VOBMX) If MSIM=3 ave. monthly max.air temp.	°C	-10-42
	(VOBMN) If MSIM=3 ave. monthly min. air temp.	°C	-30-30
	(CVT) Coefficient of variation for monthly temp.		0-1
6. Solar Radiation	(OBSL) Monthly average daily solar radiation	ly	20-750
7. Monthly Rainfal	(WI) Monthly maximum 0.5h rainfall	mm	0-125
8. Precipitation Parameters	(PRW1) Monthly prob. of wet day after a dry day		0. 001-.95
	(PRWw) Monthly prob. of a wet day after a wet day		0.01-0.95
	(RST1) Monthly mean of daily precipitation	mm	0-500
	(RST2) Monthly st. dev. of daily precipitation	mm	0.05-200
	(RST3) Monthly skew coef. of daily precipitation		1-7
9. Basin Data	(FLU) Fraction of basin in each sub-area		0-1
	(CN2) SCS runoff curve number-condition II		5-95
	(SALB) Soil Albedo		0.05-0.20
	(SNO) Initial water content of snow	mm	0-150
	(TT) Travel time from sub-basin outlets to basin outlet	hrs	0-50
	(CHS) Average channel slope	m/m	0.0001-10

Table A-1 (Continued). Model Input Requirements

	(CHL) Channel length from most distant point to sub-basin outlet	km	0.05 -200
	(CHK) Effective hydraulic conductivity in channel alluvium	m/m	0-150
	(CHN) Channel N value		0.01-0.3
	(OVN) Overland flow N value		0.01-0.3
	(RT) Return flow N value	days	0-180
	(CSS) Sediment concentration in return flow	ppm	100-1500
	(EK) USLE soils factor K		0.05-0.6
	(ECP) USLE erosion control practice factor P		0.1-1.0
	(SL) Average slope for each sub-basin	m	10-150
	(STP) Average slope steepness for each sub-basin	m/m	0.0001-.6
10. Stockpond Data (Optional)	(FP) Fraction of each sub-basin that flows into ponds		0-1
	(SAX) Total surface area of ponds in each sub-basin	ha	0-1000
	(VMX) Runoff volume from pond catchment area required to fill empty ponds	mm	0-100
	(VM) Initial pond volumes	mm	0-100
	(CS) Initial sediment concentration	ppm	0-5000
	(CFP) Normal sediment concentration	ppm	0-5000
	(HC) Hydraulic conductivity of pond bottoms	mm/hr	0-1
11. Reservoir Data (Optional)	(FR) Fraction of each sub-basin that flows into reservoirs		0-1
	(SAF) Total reservoir surface area at emergency spillway	ha	0-3000
	(VRF) Runoff volume from reservoir catchment area required to fill emergency spillway	mm	0-300
	(SAS) Total reservoir surface area at principal spillway	ha	0-1000
	(VRS) Runoff required to fill to principal spillway	mm	0-100
	(VR) Initial reservoir volumes	mm	0-100
	(RRR) Average principal spillway release rate	$m^3/s/km^2$	0-1
	(CSR) Initial sediment concentration in reservoirs	ppm	0-5000
	(CFR) Normal sediment concentration in reservoirs	ppm	0-5000
	(HCR) Hydraulic conductivity of reservoirs bottoms	mm/hr	0-1
12. Soil Data	(Z) Depth to bottom of layers	mm	10-3500
	(T1) Bulk density	t/m	0.05-2.6
	(T4) Available water capacity	mm	0-1.0
	(SC) Saturated conductivity	mm/h	0-200
	(CLA) Clay content	%	0-100
	(SIL) Silt content	%	0-100
13. Crop Data	(MO) Month of planting	mos	1-12
	(IDA) Day of month of planting	days	1-31
	(MOH) Month of harvest	mos	1-12
	(IDH) Day of month of harvest	days	1-31
	(ITIL) Code of tillage operation: 1=fall plow, 2=spring plow, 3=conservation tillage, 4=zero tillage		1-4
	(IRD) Vegetation: 1=annual, 2=perennial		1-2
	(CVM) Average annual C factor for sub-basin		0.001-0.5
	(BLAI) Maximum LAI for sub-basin		0.5-7
14. Daily Rainfall and Temperature (optional)	Daily precipitation for each sub-basin	mm	0-250
	Daily max.and min. temp.for each sub-basin	°C	-50-54



PROCEDURE: With appropriate data, enter scale at left and proceed to points representing the soil's % sand (0.10-2.0 mm), % organic matter, structure, and permeability, in that sequence. Interpolate between plotted curves. The dotted line illustrates procedure for a soil having: si+vfs 65%, sand 5%, OM 2.8%, structure 2, permeability 4. Solution: K = 0.31.

Figure A-1. Soil Erodibility Nomograph

Table A-3. Curve Number (CN) Values for Jiguey Sub-basin " Without" Project

Micro-basin ID#	Hydrologic Soil Group	Type	Landuse (ha)	(%)	CN Values	Individual CN Values	Weighted CN Values
41	B	Pasture	59.46	0.132	79	10.41	
41	B	Pasture	32.13	0.071	79	5.62	
41	B	Forest	20.73	0.046	66	3.03	
41	B	Coffee	339.10	0.751	68	51.08	70.14
42	B	Coffee	423.95	1.000	68	68.00	68.00
43	B	Forest	9.99	0.036	66	2.36	
43	B	Coffee	268.92	0.964	68	65.56	67.93
44	B	Crop	44.36	0.013	81	1.02	
44	B	Crop	1146.13	0.326	81	26.44	
44	B	Crop	40.97	0.012	81	0.95	
44	B	Scrub	8.08	0.002	70	0.16	
44	B	Pasture	104.09	0.030	79	2.34	
44	B	Forest	1454.61	0.414	66	27.35	
44	B	Coffee	712.53	0.203	68	13.80	72.06
45	B	Crop	44.17	0.070	81	5.67	
45	B	Scrub	0.97	0.002	70	0.11	
45	B	Scrub	38.28	0.061	70	4.25	
45	B	Scrub	75.96	0.120	70	8.43	
45	B	Coffee	471.51	0.747	68	50.82	69.27
46	B	Crop	7.28	0.002	81	0.13	
46	B	Crop	26.55	0.006	81	0.47	
46	B	Crop	3005.80	0.663	81	53.69	
46	B	Scrub	37.34	0.008	70	0.58	
46	B	Pasture	41.57	0.009	79	0.72	
46	B	Pasture	90.60	0.020	79	1.58	
46	B	Pasture	96.81	0.021	79	1.69	
46	B	Forest	15.63	0.003	66	0.23	
46	B	Forest	21.65	0.005	66	0.31	
46	B	Forest	150.43	0.033	66	2.19	
46	B	Forest	16.61	0.004	66	0.24	
46	B	Forest	13.32	0.003	66	0.19	
46	B	Forest	186.99	0.041	66	2.72	
46	B	Forest	42.95	0.009	66	0.63	
46	B	Coffee	30.75	0.007	68	0.46	
46	B	Coffee	48.22	0.011	68	0.72	
46	B	Coffee	98.05	0.022	68	1.47	
46	B	Coffee	57.29	0.013	68	0.86	
46	B	Coffee	24.47	0.005	68	0.37	
46	B	Coffee	20.53	0.005	68	0.31	
46	B	Coffee	501.64	0.111	68	7.52	77.09

Table A-4. Curve Number (CN) for Mahomita Sub-basin " Without" Project

Micro-basin ID#	Hydrologic Soil Group	Type	Landuse (ha)	(%)	CN Values	Individual CN Values	Weighted CN Values
51	A	Coffe	33.26	0.115	48	5.52	
51	B	Coffe	256.06	0.885	68	60.18	65.70
52	B	Coffe	291.04	1.000	68	68.00	68.00
53	B	Coffe	662.25	0.512	68	34.82	
53	A	Coffe	630.30	0.488	48	23.42	58.24
54	B	Coffe	136.20	0.366	68	24.87	
54	B	Coffe	1.61	0.004	68	0.29	
54	B	Crop	125.00	0.336	81	27.19	
54	B	Crop	49.69	0.133	81	10.81	
54	B	Crop	35.49	0.095	81	7.72	
54	B	Pasture	2.18	0.006	79	0.46	
54	B	Coffe	4.14	0.011	68	0.76	
54	B	Coffe	0.22	0.001	68	0.04	
54	B	Coffe	0.27	0.001	68	0.05	
54	B	Pasture	17.53	0.047	79	3.72	75.92
55	B	Coffe	0.02	0.000	68	0.00	
55	B	Coffe	0.64	0.000	68	0.02	
55	B	Pasture	0.01	0.000	79	0.00	
55	B	Crop	2.29	0.001	81	0.09	
55	B	Crop	0.17	0.000	81	0.01	
55	B	Crop	215.200	0.101	81.00	8.15	
55	B	Crop	55.00	0.026	81	2.08	
55	B	Crop	125.00	0.058	81	4.73	
55	B	Crop	145.20	0.068	81	5.50	
55	B	Crop	5.49	0.003	81	0.21	
55	B	Coffe	0.16	0.000	68	0.01	
55	B	Crop	12.33	0.006	81	0.47	
55	B	Coffe	15.84	0.007	68	0.50	
55	B	Coffe	0.02	0.000	68	0.00	
55	B	Pasture	32.06	0.015	79	1.18	
55	B	Coffe	693.39	0.324	68	22.04	
55	B	Coffe	99.22	0.046	68	3.15	
55	B	Scrub	100.00	0.047	70	3.27	
55	B	Scrub	160.76	0.075	70	5.26	
55	B	Crop	85.76	0.040	81	3.25	
55	B	Crop	0.22	0.000	81	0.01	
55	B	Crop	2.10	0.001	81	0.08	
55	B	Coffe	5.87	0.003	68	0.19	
55	B	Crop	0.05	0.000	81	0.00	
55	B	Coffe	0.46	0.000	68	0.01	
55	B	Coffe	23.75	0.011	68	0.75	
55	B	Pasture	6.23	0.003	79	0.23	
55	B	Coffe	14.42	0.007	68	0.46	
55	B	Coffe	19.78	0.009	68	0.63	
55	B	Pasture	75.58	0.035	79	2.79	
55	B	Coffee	0.07	0.000	68	0.00	
55	B	Pasture	6.38	0.003	79	0.24	
55	B	Crop	50.01	0.023	81	1.89	
55	B	Crop	168.87	0.079	81	6.39	
55	B	Scrub	1.61	0.001	70	0.05	

Table A-4 (Continued). Curve Number for Mahomita Sub-basin " Without" Project

Micro-basin ID#	Hydrologic Soil Group	Type	Landuse (ha)	(%)	CN Values	Individual CN Values	Weighted CN Values
55	B	Crop	0.33	0.000	81	0.01	
55	B	Crop	0.15	0.000	81	0.01	
55	B	Pasture	15.85	0.007	79	0.59	74.24
56	B	Crop	44.02	0.021	81	1.67	
56	B	Crop	3.06	0.001	81	0.11	
56	B	Crop	73.97	0.035	81	2.80	
56	B	Crop	24.72	0.012	81	0.94	
56	B	Coffee	645.83	0.302	68	20.53	
56	B	Crop	0.64	0.000	81	0.02	
56	B	Pasture	485.33	0.227	79	17.93	
56	B	Crop	0.26	0.000	81	0.01	
56	B	Crop	303.85	0.142	81	11.50	
56	B	Crop	79.80	0.037	81	3.03	
56	B	Crop	319.24	0.150	81	12.12	
56	B	Crop	63.32	0.030	81	2.40	
56	B	Coffee	38.28	0.018	68	1.22	
56	B	Coffee	56.60	0.027	68	1.80	76.08
57	B	Coffee	565.67	0.263	68	17.88	
57	C	Coffee	18.39	0.009	79	0.71	
57	C	Pasture	6.05	0.003	86	0.26	
57	B	Pasture	60.48	0.028	79	2.21	
57	B	Crop	49.53	0.023	81	1.86	
57	B	Crop	120.26	0.056	81	4.54	
57	B	Scrub	30.60	0.014	70	0.99	
57	B	Crop	284.33	0.132	81	10.72	
57	B	Pasture	4.12	0.002	79	0.15	
57	B	Pasture	394.70	0.184	79	14.51	
57	B	Coffee	4.16	0.002	68	0.13	
57	B	Pasture	0.08	0.000	79	0.00	
57	B	Coffee	263.29	0.123	68	8.33	
57	B	Pasture	2.06	0.001	79	0.08	
57	B	Crop	2.36	0.001	81	0.09	
57	B	Crop	43.55	0.020	81	1.64	
57	B	Coffee	1.70	0.001	68	0.05	
57	B	Crop	83.70	0.039	81	3.15	
57	B	Crop	15.81	0.007	81	0.60	
57	B	Pasture	7.24	0.003	79	0.27	
57	B	Coffee	19.61	0.009	68	0.62	
57	B	Pasture	171.24	0.080	79	6.30	75.10
58	B	Coffee	155.74	0.055	68	3.77	
58	C	Coffee	698.08	0.249	79	19.67	
58	B	Coffee	121.76	0.043	68	2.92	
58	B	Pasture	171.37	0.061	79	4.82	
58	C	Pasture	335.96	0.119	86	10.23	
58	B	Pasture	300.65	0.108	79	8.53	
58	B	Coffee	108.10	0.039	68	2.62	
58	B	Coffee	11.08	0.004	68	0.27	
58	C	Forest	907.04	0.323	77	24.86	77.69

Table A-5. Curve Number (CN) for Jiguey Sub-basin "With" Project (5 years)

Micro-basin	Hydrologic		Land Use		Proposed	CN	Individual	Weighted
ID#	Soil Group	Type	(ha)	%	Land Use (yr)	Values	CN Values	CN Values
41	B	Coffee	7.6	0.017		68	1.15	
41	B	Pasture	32.1	0.071		79	5.62	
41	B	Pasture	59.5	0.132		79	10.41	
41	B	Forest	20.7	0.046		66	3.03	
41	B	Coffee	323.7	0.717		68	48.76	
41	B	Coffee	7.8	0.017		68	1.18	70.14
42	B	Coffee	221.1	0.522		68	35.47	
42	B	Coffee	202.8	0.478		68	32.53	68.00
43	B	Forest	10.0	0.036		66	2.36	
43	B	Coffee	77.0	0.276		68	18.78	
43	B	Coffee	88.4	0.317		68	21.54	
43	B	Coffee	47.0	0.168		68	11.45	
43	B	Coffee	56.6	0.203		68	13.79	67.93
44	B	Crop	40.1	0.011	Coffee (3rd)	60	0.69	
44	B	Crop	0.0	0.000		81	0.00	
44	B	Crop	62.3	0.018	Coffee (3rd)	60	1.06	
44	B	Crop	4.6	0.001	Coffee (3rd)	60	0.08	
44	B	Crop	18.0	0.005	Coffee (3rd)	60	0.31	
44	B	Crop	19.8	0.006		81	0.46	
44	B	Pasture	18.8	0.005		79	0.42	
44	B	Forest	1.5	0.000		66	0.03	
44	B	Forest	0.2	0.000		66	0.00	
44	B	Forest	4.6	0.001		66	0.09	
44	B	Forest	130.9	0.037		66	2.46	
44	B	Coffee	0.0	0.000		68	0.00	
44	B	Crop	0.2	0.000		81	0.00	
44	B	Crop	41.0	0.012		81	0.95	
44	B	Crop	0.3	0.000		81	0.01	
44	B	Crop	50.0	0.014	Coffee (4th)	60	0.85	
44	B	Crop	25.0	0.007	Forestry (4th)	60	0.43	
44	B	Crop	1.8	0.001		81	0.04	
44	B	Crop	50.0	0.014	Energetic (2nd)	60	0.85	
44	B	Crop	240.5	0.068		81	5.55	
44	B	Crop	50.0	0.014	Forestry (3rd)	60	0.85	
44	B	Crop	497.9	0.142		81	11.49	
44	B	Scrub	7.6	0.002		70	0.15	
44	B	Pasture	85.3	0.024		79	1.92	
44	B	Forest	1152.5	0.328		66	21.67	
44	B	Coffee	0.0	0.000		68	0.00	
44	B	Coffee	28.7	0.008		68	0.56	
44	B	Coffee	2.7	0.001		68	0.05	
44	B	Coffee	390.2	0.111		68	7.56	
44	B	Coffee	6.2	0.002		68	0.12	
44	B	Crop	50.0	0.014	Energetic (4th)	60	0.85	
44	B	Crop	80.0	0.023		81	1.85	
44	B	Scrub	0.4	0.000		70	0.01	
44	B	Forest	46.0	0.013		66	0.86	
44	B	Forest	119.0	0.034		66	2.24	
44	B	Coffee	169.0	0.048		68	3.27	
44	B	Coffee	115.8	0.033		68	2.24	69.97

Table A-5 (Continued). Curve Number (CN) for Jiguey Sub-basin "With" Project (5 years)

Micro-basin ID#	Hydrologic Soil Group	Type	Land Use (ha)	%	Proposed Land Use (yr)	CN Values	Individual CN Values	Weighted CN Values
45	B	Scrub	0.7	0.001		70	0.08	
45	B	Crop	22.0	0.035		81	2.83	
45	B	Scrub	36.4	0.058		70	4.04	
45	B	Scrub	76.0	0.120		70	8.43	
45	B	Coffee	349.9	0.555		68	37.71	
45	B	Crop	2.1	0.003		81	0.27	
45	B	Crop	20.0	0.032		81	2.57	
45	B	Scrub	1.9	0.003		70	0.21	
45	B	Scrub	0.3	0.000		70	0.03	
45	B	Scrub	0.0	0.000		70	0.00	
45	B	Coffee	109.8	0.174		68	11.84	
45	B	Coffee	11.8	0.019		68	1.27	69.28
46	B	Crop	1.1	0.000		81	0.02	
46	B	Crop	8.0	0.002	Coffee (2nd)	60	0.11	
46	B	Crop	14.0	0.003	Coffee (2nd)	60	0.19	
46	B	Crop	3.9	0.001	Coffee (2nd)	60	0.05	
46	B	Crop	12.1	0.003	Coffee (2nd)	60	0.16	
46	B	Crop	0.0	0.000		81	0.00	
46	B	Crop	0.5	0.000		81	0.01	
46	B	Crop	3.1	0.001	Coffee (2nd)	60	0.04	
46	B	Crop	16.0	0.004	Coffee (2nd)	60	0.21	
46	B	Crop	0.4	0.000		81	0.01	
46	B	Crop	33.2	0.007	Coffee (2nd)	60	0.44	
46	B	Crop	0.0	0.000		81	0.00	
46	B	Crop	40.5	0.009	Coffee (2nd)	60	0.54	
46	B	Crop	0.1	0.000		81	0.00	
46	B	Crop	57.5	0.013	Coffee (2nd)	60	0.76	
46	B	Crop	0.1	0.000		81	0.00	
46	B	Crop	50.0	0.011	Enegetic (3rd)	60	0.66	
46	B	Crop	9.5	0.002	Coffee (5th)	60	0.13	
46	B	Crop	75.0	0.017	Forestry (5th)	60	0.99	
46	B	Crop	0.6	0.000		81	0.01	
46	B	Crop	28.4	0.006	Coffee (5th)	60	0.38	
46	B	Crop	50.0	0.011	Energetic (1st)	60	0.66	
46	B	Crop	82.6	0.018	Coffee (2nd)	60	1.09	
46	B	Crop	15.0	0.003	Coffee (2nd)	60	0.20	
46	B	Crop	8.3	0.002	Coffee (5th)	60	0.11	
46	B	Crop	8.8	0.002	Coffee (2nd)	60	0.12	
46	B	Crop	5.1	0.001	Coffee (2nd)	60	0.07	
46	B	Pasture	3.2	0.001		79	0.06	
46	B	Forest	1.3	0.000		66	0.02	
46	B	Forest	0.1	0.000		66	0.00	
46	B	Forest	0.6	0.000		66	0.01	
46	B	Forest	0.3	0.000		66	0.00	
46	B	Forest	59.3	0.013		66	0.86	
46	B	Coffee	0.5	0.000		68	0.01	
46	B	Coffee	4.0	0.001		68	0.06	
46	B	Coffee	11.0	0.002		68	0.17	
46	B	Coffee	12.4	0.003		68	0.19	
46	B	Coffee	10.1	0.002		68	0.15	

Table A-5 (Continued). Curve Number (CN) for Jiguey Sub-basin "With" Project (5 years,

Micro-basin	Hydrologic		Land Use		Proposed	CN	Individual	Weighted
ID#	Soil Group	Type	(ha)	%	Land Use (yr)	Values	CN Values	CN Values
46	B	Coffee	20.0	0.004		68	0.30	
46	B	Coffee	25.8	0.006		68	0.39	
46	B	Coffee	1.6	0.000		68	0.02	
46	B	Coffee	9.1	0.002		68	0.14	
46	B	Coffee	5.7	0.001		68	0.08	
46	B	Crop	103.8	0.023	Coffee (5th)	60	1.37	
46	B	Crop	50.0	0.011	Energetic (5th)	60	0.66	
46	B	Crop	100.0	0.022	Forestry (4th)	60	1.32	
46	B	Crop	415.5	0.092		81	7.42	
46	B	Crop	175.0	0.039	Coffee (3rd)	60	2.32	
46	B	Crop	100.0	0.022	Forestry (1st)	60	1.32	
46	B	Crop	150.0	0.033	Coffee (1st)	60	1.98	
46	B	Crop	75.0	0.017	Forestry (3rd)	60	0.99	
46	B	Crop	971.3	0.214		81	17.35	
46	B	Crop	250.0	0.055	Coffee (4th)	60	3.31	
46	B	Crop	125.0	0.028	Forestry (2nd)	60	1.65	
46	B	Scrub	32.2	0.007		70	0.50	
46	B	Pasture	8.5	0.002		79	0.15	
46	B	Pasture	29.8	0.007		79	0.52	
46	B	Pasture	59.6	0.013		79	1.04	
46	B	Pasture	96.8	0.021		79	1.69	
46	B	Forest	16.6	0.004		66	0.24	
46	B	Forest	21.6	0.005		66	0.32	
46	B	Forest	61.9	0.014		66	0.90	
46	B	Forest	26.6	0.006		66	0.39	
46	B	Forest	12.7	0.003		66	0.19	
46	B	Forest	15.5	0.003		66	0.23	
46	B	Forest	187.0	0.041		66	2.72	
46	B	Forest	1.0	0.000		66	0.02	
46	B	Forest	43.0	0.009		66	0.63	
46	B	Coffee	20.0	0.004		68	0.30	
46	B	Coffee	29.1	0.006		68	0.44	
46	B	Coffee	1.7	0.000		68	0.02	
46	B	Coffee	74.3	0.016		68	1.11	
46	B	Coffee	1.0	0.000		68	0.02	
46	B	Coffee	1.9	0.000		68	0.03	
46	B	Coffee	0.1	0.000		68	0.00	
46	B	Coffee	11.4	0.003		68	0.17	
46	B	Coffee	16.0	0.004		68	0.24	
46	B	Coffee	12.7	0.003		68	0.19	
46	B	Coffee	16.8	0.004		68	0.25	
46	B	Coffee	17.8	0.004		68	0.27	
46	B	Coffee	105.4	0.023		68	1.58	
46	B	Coffee	91.5	0.020		68	1.37	
46	B	Scrub	5.1	0.001		70	0.08	
46	B	Pasture	11.5	0.003		79	0.20	
46	B	Pasture	19.5	0.004		79	0.34	
46	B	Coffee	262.1	0.058		68	3.93	
46	B	Coffee	18.9	0.004		68	0.28	69.45

Table A-6. Curve Number (CN) for Mahomita Sub-basin "With" Project (5 years)

Micro-basin ID#	Hydrologic Soil Group	Type	Land Use (ha)	%	Proposed Land Use (yr)	CN Values	Individual CN Values	Weighted CN Values
51	A	Coffe	33.26	0.115		48	5.52	
51	B	Coffe	256.06	0.885		68	60.18	65.70
52	B	Coffe	291.04	1.000		68	68.00	68.00
53	B	Coffe	662.25	0.512		68	34.82	
53	A	Coffe	630.30	0.488		48	23.42	58.24
54	B	Coffe	136.20	0.366		68	24.87	
54	B	Coffe	1.61	0.004		68	0.29	
54	B	Crop	50.00	0.134		81	10.88	
54	B	Crop	75.00	0.201	Forestry (1st)	60	12.09	
54	B	Crop	50.00	0.134	Forestry (2nd)	60	8.06	
54	B	Crop	35.19	0.095	Forestry (3rd)	60	5.67	
54	B	Pasture	4.89	0.013		79	1.04	
54	B	Coffe	4.14	0.011		68	0.76	
54	B	Coffe	0.22	0.001		68	0.04	
54	B	Coffe	0.27	0.001		68	0.05	
54	B	Pasture	14.81	0.040	Forestry (3rd)	60	2.39	66.13
55	B	Coffe	0.02	0.000		68	0.00	
55	B	Coffe	0.64	0.000		68	0.02	
55	B	Pasture	0.01	0.000		79	0.00	
55	B	Crop	3.18	0.001		81	0.12	
55	B	Crop	0.17	0.000		81	0.01	
55	B	Crop	200.000	0.093	Coffee (2nd)	60.00	5.61	
55	B	Crop	55.00	0.026	Energetic (1st)	60	1.54	
55	B	Crop	125.00	0.058	Coffee (1st)	60	3.51	
55	B	Crop	100.00	0.047	Coffee (3rd)	60	2.80	
55	B	Crop	65.00	0.030	Coffee (4th)	60	1.82	
55	B	Coffe	0.16	0.000		68	0.01	
55	B	Crop	5.00	0.002		81	0.19	
55	B	Coffe	15.84	0.007		68	0.50	
55	B	Coffe	0.02	0.000		68	0.00	
55	B	Pasture	32.06	0.015		79	1.18	
55	B	Coffe	693.39	0.324		68	22.04	
55	B	Coffe	99.22	0.046		68	3.15	
55	B	Scrub	100.00	0.047		70	3.27	
55	B	Scrub	160.28	0.075		70	5.24	
55	B	Crop	75.00	0.035	Forest (4th)	60	2.10	
55	B	Crop	10.98	0.005		81	0.42	
55	B	Crop	2.10	0.001		81	0.08	
55	B	Coffe	5.87	0.003		68	0.19	
55	B	Crop	43.93	0.021		81	1.66	
55	B	Coffe	0.46	0.000		68	0.01	
55	B	Coffe	23.75	0.011		68	0.75	
55	B	Pasture	6.23	0.003		79	0.23	
55	B	Coffe	14.42	0.007		68	0.46	
55	B	Coffe	19.78	0.009		68	0.63	
55	B	Pasture	75.58	0.035		79	2.79	
55	B	Coffee	0.07	0.000		68	0.00	
55	B	Pasture	6.38	0.003		79	0.24	
55	B	Crop	50.00	0.023	Forestry (1st)	60	1.40	
55	B	Crop	75.00	0.035	Forestry (3rd)	60	2.10	

Table A-6 (Continued). Curve Number for Mahomita Sub-basin "With" Project (5 years)

Micro-basin ID#	Hydrologic Soil Group	Type	Land Use (ha)	%	Proposed Land Use (yr)	CN Values	Individual CN Values	Weighted CN Values
55	B	Scrub	1.61	0.001		70	0.05	
55	B	Crop	55.00	0.026	Energetic (3rd)	60	1.54	
55	B	Crop	2.80	0.001		81	0.11	
55	B	Pasture	15.85	0.007		79	0.59	66.37
56	B	Crop	21.05	0.010		81	0.80	
56	B	Crop	50.00	0.023	Forestry (3rd)	60	1.40	
56	B	Crop	50.00	0.023	Forestry (2nd)	60	1.40	
56	B	Crop	24.72	0.012		81	0.94	
56	B	Coffee	645.83	0.302		68	20.53	
56	B	Crop	8.96	0.004		81	0.34	
56	B	Pasture	485.33	0.227		79	17.93	
56	B	Crop	5.26	0.002		81	0.20	
56	B	Ext. Cro	55.00	0.026	Charcoal (4th)	60	1.54	
56	B	Ext. Cro	100.00	0.047	Coffee (5th)	60	2.81	
56	B	Ext. Cro	547.90	0.256		81	20.75	
56	B	Crop	50.00	0.023	Forestry (4th)	60	1.40	
56	B	Coffee	38.28	0.018		68	1.22	
56	B	Coffee	56.60	0.026		68	1.80	73.05
57	B	Coffee	565.67	0.263		68	17.90	
57	C	Coffee	18.39	0.009		79	0.68	
57	C	Pasture	6.05	0.003		86	0.24	
57	B	Pasture	55.00	0.026	Energetic (2nd)	60	1.54	
57	B	Crop	50.00	0.023	Forestry (4th)	60	1.40	
57	B	Crop	100.00	0.047	Forestry (5th)	60	2.79	
57	B	Crop	75.00	0.035	Forestry (2nd)	60	2.09	
57	B	Scrub	30.60	0.014		70	1.00	
57	B	Crop	55.00	0.026	Energetic (5th)	60	1.54	
57	B	Crop	135.00	0.063	Coffee (4th)	60	3.77	
57	B	Pasture	4.12	0.002		79	0.15	
57	B	Pasture	394.70	0.184		79	14.51	
57	B	Coffee	4.16	0.002		68	0.13	
57	B	Pasture	0.08	0.000		79	0.00	
57	B	Coffee	263.29	0.123		68	8.33	
57	B	Pasture	2.06	0.001		79	0.08	
57	B	Crop	41.48	0.019		81	1.56	
57	B	Crop	100.00	0.047	Coffee (3rd)	60	2.79	
57	B	Coffee	1.70	0.001		68	0.05	
57	B	Crop	27.25	0.013		81	1.03	
57	B	Crop	15.81	0.007		81	0.60	
57	B	Pasture	12.72	0.006		79	0.47	
57	B	Coffee	19.61	0.009		68	0.62	
57	B	Pasture	171.24	0.080		79	6.30	69.56
58	B	Coffee	155.74	0.055		68	3.77	
58	C	Coffee	698.08	0.249		79	19.67	
58	B	Coffee	121.76	0.043		68	2.92	
58	B	Pasture	171.37	0.061		79	4.82	
58	C	Pasture	335.96	0.120		86	10.28	
58	B	Pasture	300.65	0.108		79	8.53	
58	B	Coffee	108.10	0.039		68	2.62	
58	B	Coffee	11.08	0.004		68	0.27	
58	C	Forest	907.04	0.323		77	24.86	77.73

Table A-7. C Values for Jiguey Sub-basin "Without" Project

Micro-basin	Land use			Potential	C	Individual	Weighted
ID#	Type	(ha)	%	Land use	Factor	C Values	C Values
41	Coffee	7.61	0.017	Agroforestry	0.045	0.0008	
41	Pasture	32.13	0.071	Forestry	0.042	0.0030	
41	Pasture	59.46	0.132	Forestry	0.042	0.0055	
41	Forest	20.73	0.046	Forestry	0.003	0.0001	
41	Coffee	323.68	0.717	Forestry	0.045	0.0323	
41	Coffee	7.81	0.017	Silvopastoral	0.045	0.0008	0.0425
42	Coffee	221.14	0.522	Protection	0.045	0.0235	
42	Coffee	202.81	0.478	Silvopastoral	0.045	0.0215	0.0450
43	Forest	9.99	0.036	Forestry	0.003	0.0001	
43	Coffee	77.02	0.276	Forestry	0.045	0.0124	
43	Coffee	88.36	0.317	Forestry	0.045	0.0143	
43	Coffee	46.98	0.168	Silvopastoral	0.045	0.0076	
43	Coffee	56.57	0.203	Silvopastoral	0.045	0.0091	0.0435
44	Crop	40.13	0.011	Agroforestry	0.400	0.0046	
44	Crop	0.03	0.000	Agroforestry	0.400	0.0000	
44	Crop	62.30	0.018	Agroforestry	0.400	0.0071	
44	Crop	4.60	0.001	Agroforestry	0.400	0.0005	
44	Crop	17.97	0.005	Agroforestry	0.400	0.0020	
44	Crop	19.80	0.006	Agroforestry	0.400	0.0023	
44	Pasture	18.79	0.005	Agroforestry	0.042	0.0002	
44	Forest	1.52	0.000	Agroforestry	0.003	0.0000	
44	Forest	0.16	0.000	Agroforestry	0.003	0.0000	
44	Forest	4.59	0.001	Agroforestry	0.003	0.0000	
44	Forest	130.88	0.037	Agroforestry	0.003	0.0001	
44	Coffee	0.04	0.000	Agroforestry	0.045	0.0000	
44	Crop	0.15	0.000	Forestry	0.400	0.0000	
44	Crop	50.00	0.014	Forestry	0.400	0.0057	
44	Crop	0.31	0.000	Forestry	0.400	0.0000	
44	Crop	50.00	0.014	Forestry	0.400	0.0057	
44	Crop	25.00	0.007	Forestry	0.400	0.0028	
44	Crop	490.48	0.140	Forestry	0.400	0.0559	
44	Crop	50.00	0.014	Forestry	0.400	0.0057	
44	Crop	240.47	0.068	Forestry	0.400	0.0274	
44	Crop	50.00	0.014	Forestry	0.400	0.0057	
44	Crop	0.21	0.000	Forestry	0.400	0.0000	
44	Scrub	7.63	0.002	Forestry	0.090	0.0002	
44	Pasture	85.31	0.024	Forestry	0.042	0.0010	
44	Forest	1152.48	0.328	Forestry	0.003	0.0010	
44	Coffee	0.01	0.000	Forestry	0.045	0.0000	
44	Coffee	28.72	0.008	Forestry	0.045	0.0004	
44	Coffee	2.65	0.001	Forestry	0.045	0.0000	
44	Coffee	390.24	0.111	Forestry	0.045	0.0050	
44	Coffee	6.14	0.002	Protection	0.045	0.0001	
44	Crop	50.00	0.014	Silvopastoral	0.400	0.0057	
44	Crop	80.01	0.023	Silvopastoral	0.400	0.0091	
44	Forest	45.98	0.013	Silvopastoral	0.003	0.0000	
44	Forest	119.01	0.034	Silvopastoral	0.003	0.0001	
44	Coffee	168.98	0.048	Silvopastoral	0.045	0.0022	
44	Scrub	0.43	0.000	Silvopastoral	0.090	0.0000	
44	Coffee	115.78	0.033	Silvopastoral	0.045	0.0015	0.1956

Table A-7 (Continued). C Values for Jiguey Sub-basin "Without" Project

Micro-basin ID#	Type	Land use (ha)	%	Potential Land use	C Factor	Individual C Values	Weighted C Values
45	Scrub	0.71	0.001	Forestry	0.090	0.0001	
45	Crop	22.04	0.035	Protection	0.400	0.0140	
45	Scrub	36.43	0.058	Protection	0.090	0.0052	
45	Scrub	75.96	0.120	Protection	0.090	0.0108	
45	Coffee	349.90	0.555	Protection	0.045	0.0250	
45	Crop	2.13	0.003	Silvopastoral	0.400	0.0013	
45	Crop	20.00	0.032	Silvopastoral	0.400	0.0127	
45	Scrub	1.85	0.003	Silvopastoral	0.090	0.0003	
45	Scrub	0.25	0.000	Silvopastoral	0.090	0.0000	
45	Scrub	0.01	0.000	Silvopastoral	0.090	0.0000	
45	Coffee	109.83	0.174	Silvopastoral	0.045	0.0078	
45	Coffee	11.78	0.019	Silvopastoral	0.045	0.0008	0.0781
46	Crop	1.11	0.000	Agroforestry	0.400	0.0001	
46	Crop	8.01	0.002	Agroforestry	0.400	0.0007	
46	Crop	14.02	0.003	Agroforestry	0.400	0.0012	
46	Crop	3.90	0.001	Agroforestry	0.400	0.0003	
46	Crop	12.12	0.003	Agroforestry	0.400	0.0011	
46	Crop	0.05	0.000	Agroforestry	0.400	0.0000	
46	Crop	0.54	0.000	Agroforestry	0.400	0.0000	
46	Crop	3.07	0.001	Agroforestry	0.400	0.0003	
46	Crop	16.02	0.004	Agroforestry	0.400	0.0014	
46	Crop	0.44	0.000	Agroforestry	0.400	0.0000	
46	Crop	33.23	0.007	Agroforestry	0.400	0.0029	
46	Crop	0.01	0.000	Agroforestry	0.400	0.0000	
46	Crop	40.53	0.009	Agroforestry	0.400	0.0036	
46	Crop	0.10	0.000	Agroforestry	0.400	0.0000	
46	Crop	57.53	0.013	Agroforestry	0.400	0.0051	
46	Crop	0.09	0.000	Agroforestry	0.400	0.0000	
46	Crop	50.00	0.011	Agroforestry	0.400	0.0044	
46	Crop	9.49	0.002	Agroforestry	0.400	0.0008	
46	Crop	75.00	0.017	Agroforestry	0.400	0.0066	
46	Crop	0.59	0.000	Agroforestry	0.400	0.0001	
46	Crop	28.40	0.006	Agroforestry	0.400	0.0025	
46	Crop	8.33	0.002	Agroforestry	0.400	0.0007	
46	Crop	50.00	0.011	Agroforestry	0.400	0.0044	
46	Crop	82.57	0.018	Agroforestry	0.400	0.0073	
46	Crop	15.03	0.003	Agroforestry	0.400	0.0013	
46	Crop	8.83	0.002	Agroforestry	0.400	0.0008	
46	Crop	5.14	0.001	Agroforestry	0.400	0.0005	
46	Pasture	3.22	0.001	Agroforestry	0.042	0.0000	
46	Forest	0.27	0.000	Agroforestry	0.003	0.0000	
46	Forest	59.34	0.013	Agroforestry	0.003	0.0000	
46	Coffee	0.49	0.000	Agroforestry	0.045	0.0000	
46	Coffee	3.97	0.001	Agroforestry	0.045	0.0000	
46	Coffee	11.01	0.002	Agroforestry	0.045	0.0001	
46	Forest	1.90	0.000	Agroforestry	0.003	0.0000	
46	Forest	0.12	0.000	Agroforestry	0.003	0.0000	
46	Coffee	10.10	0.002	Agroforestry	0.045	0.0001	
46	Coffee	12.38	0.003	Agroforestry	0.045	0.0001	
46	Coffee	19.98	0.004	Agroforestry	0.045	0.0002	

Table A-7 (Continued). C Values for Jiguey Sub-basin "Without" Project

Micro-basin ID#	Type	Land use (ha)	%	Potential Land use	C Factor	Individual C Values	Weighted C Values
46	Coffee	25.78	0.006	Agroforestry	0.045	0.0003	
46	Coffee	1.65	0.000	Agroforestry	0.045	0.0000	
46	Coffee	9.14	0.002	Agroforestry	0.045	0.0001	
46	Coffee	5.66	0.001	Agroforestry	0.045	0.0001	
46	Crop	103.78	0.023	Agroforestry	0.400	0.0092	
46	Crop	50.00	0.011	Agroforestry	0.400	0.0044	
46	Crop	100.00	0.022	Agroforestry	0.400	0.0088	
46	Crop	434.64	0.096	Agroforestry	0.400	0.0383	
46	Crop	175.00	0.039	Agroforestry	0.400	0.0154	
46	Crop	100.00	0.022	Agroforestry	0.400	0.0088	
46	Crop	75.00	0.017	Agroforestry	0.400	0.0066	
46	Crop	150.00	0.033	Agroforestry	0.400	0.0132	
46	Crop	952.14	0.210	Agroforestry	0.400	0.0840	
46	Crop	250.00	0.055	Agroforestry	0.400	0.0221	
46	Crop	125.00	0.028	Agroforestry	0.400	0.0110	
46	Scrub	32.20	0.007	Agroforestry	0.090	0.0006	
46	Pasture	8.51	0.002	Agroforestry	0.042	0.0001	
46	Pasture	29.84	0.007	Agroforestry	0.042	0.0003	
46	Pasture	59.55	0.013	Agroforestry	0.042	0.0006	
46	Pasture	96.81	0.021	Agroforestry	0.042	0.0009	
46	Forest	16.61	0.004	Agroforestry	0.003	0.0000	
46	Forest	21.65	0.005	Agroforestry	0.003	0.0000	
46	Forest	61.90	0.014	Agroforestry	0.003	0.0000	
46	Forest	26.58	0.006	Agroforestry	0.003	0.0000	
46	Forest	12.72	0.003	Agroforestry	0.003	0.0000	
46	Forest	15.51	0.003	Agroforestry	0.003	0.0000	
46	Forest	186.99	0.041	Agroforestry	0.003	0.0001	
46	Forest	1.05	0.000	Agroforestry	0.003	0.0000	
46	Forest	42.95	0.009	Agroforestry	0.003	0.0000	
46	Coffee	20.00	0.004	Agroforestry	0.045	0.0002	
46	Coffee	29.10	0.006	Agroforestry	0.045	0.0003	
46	Coffee	1.66	0.000	Agroforestry	0.045	0.0000	
46	Coffee	74.33	0.016	Agroforestry	0.045	0.0007	
46	Coffee	0.00	0.000	Agroforestry	0.045	0.0000	
46	Coffee	1.01	0.000	Agroforestry	0.045	0.0000	
46	Coffee	11.41	0.003	Agroforestry	0.045	0.0001	
46	Coffee	12.71	0.003	Agroforestry	0.045	0.0001	
46	Coffee	16.83	0.004	Agroforestry	0.045	0.0002	
46	Coffee	17.84	0.004	Agroforestry	0.045	0.0002	
46	Coffee	105.41	0.023	Agroforestry	0.045	0.0010	
46	Coffee	1.93	0.000	Agroforestry	0.045	0.0000	
46	Coffee	15.96	0.004	Agroforestry	0.045	0.0002	
46	Coffee	91.52	0.020	Protection	0.045	0.0009	
46	Scrub	5.14	0.001	Silvopastoral	0.090	0.0001	
46	Pasture	11.54	0.003	Silvopastoral	0.042	0.0001	
46	Pasture	19.51	0.004	Silvopastoral	0.042	0.0002	
46	Coffee	262.10	0.058	Silvopastoral	0.045	0.0026	
46	Coffee	18.87	0.004	Silvopastoral	0.045	0.0002	0.2790

Table A-8. Computed C Values for Mahomita Sub-basin "Without" Project

Micro-basin ID#	Type	Land use (ha)	%	Potential Land use	C Factor	Individual C Values	Weighted C Values
51	Coffe	289.33	1.000	Forestry	0.045	0.0450	0.0450
52	Coffe	291.04	1.000	Protection	0.045	0.0450	0.0450
53	Coffe	869.75	0.673	Forestry	0.045	0.0303	
53	Coffe	3.45	0.003	Agroforestry	0.045	0.0001	
53	Coffe	419.35	0.324	Agroforestry	0.045	0.0146	0.0450
54	Coffe	136.20	0.366	Protection	0.045	0.0165	
54	Coffe	1.61	0.004	Protection	0.045	0.0002	
54	Crop	3.61	0.010	Protection	0.400	0.0039	
54	Crop	125.00	0.336	Protection	0.400	0.1344	
54	Crop	46.09	0.124	Protection	0.400	0.0494	
54	Crop	35.49	0.095	Protection	0.400	0.0380	
54	Pasture	2.18	0.006	Protection	0.042	0.0002	
54	Coffe	4.14	0.011	Agroforestry	0.045	0.0005	
54	Coffe	0.22	0.001	Agroforestry	0.045	0.0000	
54	Coffe	0.27	0.001	Forestry	0.045	0.0000	
54	Pasture	17.53	0.047	Protection	0.042	0.0020	0.2452
55	Coffe	0.02	0.000	Agroforestry	0.045	0.0000	
55	Coffe	0.64	0.000	Agroforestry	0.045	0.0000	
55	Pasture	0.01	0.000	Protection	0.042	0.0000	
55	Crop	2.29	0.001	Agroforestry	0.400	0.0004	
55	Crop	0.17	0.000	Protection	0.400	0.0000	
55	Crop	215.20	0.100	Agroforestry	0.400	0.0401	
55	Crop	55.00	0.026	Agroforestry	0.400	0.0103	
55	Crop	125.00	0.056	Agroforestry	0.400	0.0225	
55	Crop	145.20	0.065	Agroforestry	0.400	0.0261	
55	Crop	5.49	0.003	Protection	0.400	0.0010	
55	Coffe	0.16	0.000	Agroforestry	0.045	0.0000	
55	Crop	12.33	0.006	Agroforestry	0.400	0.0023	
55	Coffe	15.84	0.007	Agroforestry	0.045	0.0003	
55	Coffe	0.02	0.000	Agroforestry	0.045	0.0000	
55	Pasture	32.06	0.015	Agroforestry	0.042	0.0006	
55	Coffe	693.39	0.324	Agroforestry	0.045	0.0146	
55	Coffe	99.22	0.046	Protection	0.045	0.0021	
55	Scrub	100.00	0.047	Protection	0.090	0.0042	
55	Scrub	160.28	0.075	Protection	0.090	0.0067	
55	Crop	85.76	0.040	Protection	0.400	0.0160	
55	Crop	0.22	0.000	Protection	0.400	0.0000	
55	Crop	2.10	0.001	Protection	0.400	0.0004	
55	Coffe	5.87	0.003	Protection	0.045	0.0001	
55	Crop	0.05	0.000	Agroforestry	0.400	0.0000	
55	Coffe	0.46	0.000	Protection	0.045	0.0000	
55	Coffe	23.75	0.011	Forestry	0.045	0.0005	
55	Pasture	6.23	0.003	Protection	0.042	0.0001	
55	Coffe	14.42	0.007	Protection	0.045	0.0003	
55	Coffe	19.78	0.009	Protection	0.045	0.0004	
55	Pasture	75.58	0.049	Protection	0.042	0.0021	
55	Coffee	0.07	0.000	Agroforestry	0.045	0.0000	
55	Pasture	6.38	0.003	Protection	0.042	0.0001	
55	Crop	50.01	0.023	Protection	0.400	0.0093	
55	Crop	168.87	0.079	Protection	0.400	0.0316	

Table A-8 (Continued). Computed C Values for Mahomita Sub-basin "Without" Project

Micro-basin ID#	Type	Land use (ha)	%	Potential Land use	C Factor	Individual C Values	Weighted C Values
55	Scrub	1.61	0.001	Agroforestry	0.090	0.0001	
55	Crop	0.33	0.000	Agroforestry	0.400	0.0001	
55	Crop	0.15	0.000	Protection	0.400	0.0000	
55	Pasture	15.85	0.007	Agroforestry	0.042	0.0003	0.1930
56	Crop	44.02	0.021	Agroforestry	0.400	0.0082	
56	Crop	3.06	0.001	Agroforestry	0.400	0.0006	
56	Crop	73.97	0.035	Agroforestry	0.400	0.0138	
56	Crop	24.72	0.012	Agroforestry	0.400	0.0046	
56	Coffee	645.83	0.302	Agroforestry	0.045	0.0136	
56	Crop	0.64	0.000	Agroforestry	0.400	0.0001	
56	Pasture	485.33	0.227	Agroforestry	0.042	0.0095	
56	Crop	0.26	0.000	Agroforestry	0.400	0.0000	
56	Ext. Crop	303.85	0.142	Agroforestry	0.120	0.0170	
56	Ext. Crop	79.80	0.037	Agroforestry	0.120	0.0045	
56	Ext. Crop	319.24	0.150	Agroforestry	0.120	0.0180	
56	Crop	63.32	0.030	Agroforestry	0.400	0.0118	
56	Coffee	38.28	0.018	Agroforestry	0.045	0.0008	
56	Coffee	56.60	0.027	Agroforestry	0.045	0.0012	0.1039
57	Coffee	584.06	0.272	Protection	0.045	0.0122	
57	Pasture	66.53	0.031	Agroforestry	0.042	0.0013	
57	Crop	49.53	0.023	Agroforestry	0.400	0.0092	
57	Crop	120.26	0.056	Protection	0.400	0.0224	
57	Scrub	30.60	0.014	Protection	0.090	0.0013	
57	Crop	284.33	0.132	Protection	0.400	0.0529	
57	Pasture	4.12	0.002	Protection	0.042	0.0001	
57	Pasture	394.70	0.184	Protection	0.042	0.0077	
57	Coffee	4.16	0.002	Protection	0.045	0.0001	
57	Pasture	0.08	0.000	Protection	0.042	0.0000	
57	Coffee	263.29	0.123	Agroforestry	0.045	0.0055	
57	Pasture	2.06	0.001	Agroforestry	0.042	0.0000	
57	Ext. Crop	2.36	0.001	Agroforestry	0.120	0.0001	
57	Crop	43.55	0.020	Agroforestry	0.400	0.0081	
57	Coffee	1.70	0.001	Protection	0.045	0.0000	
57	Crop	83.70	0.039	Agroforestry	0.400	0.0156	
57	Crop	15.81	0.007	Agroforestry	0.400	0.0030	
57	Pasture	7.24	0.003	Agroforestry	0.042	0.0001	
57	Coffee	19.61	0.009	Protection	0.045	0.0004	
57	Pasture	171.24	0.080	Protection	0.042	0.0033	0.1435
58	Coffee	155.74	0.055	Protection	0.045	0.0025	
58	Coffee	819.84	0.292	Protection	0.045	0.0131	
58	Pasture	171.37	0.061	Protection	0.042	0.0026	
58	Pasture	636.61	0.227	Protection	0.042	0.0095	
58	Coffee	108.10	0.039	Protection	0.045	0.0017	
58	Coffee	11.08	0.004	Protection	0.045	0.0002	
58	Forest	907.04	0.323	Protection	0.003	0.0010	0.0306

Table A-9. Computed C Values for Jiguey Sub-basin "With" Project (5 years)

Micro-basin ID#	Type	Land use (ha)	%	Potential Land use	Proposed Land use (yr)	C Factor	Individual C Values	Weighted C Values
41	Coffe	7.6	0.017	Agroforestry		0.045	0.0008	
41	Pasture	32.1	0.071	Forestry		0.042	0.0030	
41	Pasture	59.5	0.132	Forestry		0.042	0.0055	
41	Forest	20.7	0.046	Forestry		0.003	0.0001	
41	Coffe	323.7	0.717	Forestry		0.045	0.0323	
41	Coffe	7.8	0.017	Silvopastoral		0.045	0.0008	0.0425
42	Coffe	221.1	0.522	Protection		0.045	0.0235	
42	Coffe	202.8	0.478	Silvopastoral		0.045	0.0215	0.0450
43	Forest	10.0	0.036	Forestry		0.003	0.0001	
43	Coffe	77.0	0.276	Forestry		0.045	0.0124	
43	Coffe	88.4	0.317	Forestry		0.045	0.0143	
43	Coffe	47.0	0.168	Silvopastoral		0.045	0.0076	
43	Coffe	56.6	0.203	Silvopastoral		0.045	0.0091	0.0435
44	Crop	40.1	0.011	Agroforestry	Coffee (3rd)	0.039	0.0004	
44	Crop	0.0	0.000	Agroforestry		0.400	0.0000	
44	Crop	62.3	0.018	Agroforestry	Coffee (3rd)	0.039	0.0007	
44	Crop	4.6	0.001	Agroforestry	Coffee (3rd)	0.039	0.0001	
44	Crop	18.0	0.005	Agroforestry	Coffee (3rd)	0.039	0.0002	
44	Crop	19.8	0.006	Agroforestry		0.400	0.0023	
44	Pasture	18.8	0.005	Agroforestry		0.042	0.0002	
44	Forest	1.5	0.000	Agroforestry		0.003	0.0000	
44	Forest	0.2	0.000	Agroforestry		0.003	0.0000	
44	Forest	4.6	0.001	Agroforestry		0.003	0.0000	
44	Forest	130.9	0.037	Agroforestry		0.003	0.0001	
44	Coffe	0.0	0.000	Agroforestry		0.045	0.0000	
44	Crop	0.2	0.000	Forestry		0.400	0.0000	
44	Crop	50.0	0.014	Forestry		0.400	0.0057	
44	Crop	0.3	0.000	Forestry		0.400	0.0000	
44	Crop	50.0	0.014	Forestry	Coffee (4th)	0.039	0.0006	
44	Crop	25.0	0.007	Forestry	Forestry (4th)	0.003	0.0000	
44	Crop	490.5	0.140	Forestry		0.400	0.0559	
44	Crop	50.0	0.014	Forestry	Energetic (2nd)	0.009	0.0001	
44	Crop	240.5	0.068	Forestry		0.400	0.0274	
44	Crop	50.0	0.014	Forestry	Forestry (3rd)	0.003	0.0000	
44	Crop	0.2	0.000	Forestry		0.400	0.0000	
44	Scrub	7.6	0.002	Forestry		0.090	0.0002	
44	Pasture	85.3	0.024	Forestry		0.042	0.0010	
44	Forest	1152.5	0.328	Forestry		0.003	0.0010	
44	Coffe	0.0	0.000	Forestry		0.045	0.0000	
44	Coffe	28.7	0.008	Forestry		0.045	0.0004	
44	Coffe	2.7	0.001	Forestry		0.045	0.0000	
44	Coffe	390.2	0.111	Forestry		0.045	0.0050	
44	Coffe	6.2	0.002	Protection		0.045	0.0001	
44	Crop	50.0	0.014	Silvopastoral	Energetic (4th)	0.009	0.0001	
44	Crop	80.0	0.023	Silvopastoral		0.400	0.0091	
44	Scrub	0.4	0.000	Silvopastoral		0.090	0.0000	
44	Forest	46.0	0.013	Silvopastoral		0.003	0.0000	
44	Forest	119.0	0.034	Silvopastoral		0.003	0.0001	
44	Coffe	169.0	0.048	Silvopastoral		0.045	0.0022	
44	Coffe	115.8	0.033	Silvopastoral		0.045	0.0015	0.1145

Table A-9 (Continued). Computed C Values for Jiguey Sub-basin "With" Project (5 years)

Micro-basin		Land use		Potential		C	Individual	Weighted
ID#	Type	(ha)	%	Land use	Type(yr)	Factor	C Values	C Values
45	Scrub	0.7	0.001	Forestry		0.090	0.0001	
45	Crop	22.0	0.035	Protection		0.400	0.0140	
45	Scrub	36.4	0.058	Protection		0.090	0.0052	
45	Scrub	76.0	0.120	Protection		0.090	0.0108	
45	Coffe	349.9	0.555	Protection		0.045	0.0250	
45	Crop	2.1	0.003	Silvopastoral		0.400	0.0013	
45	Crop	20.0	0.032	Silvopastoral		0.400	0.0127	
45	Scrub	1.9	0.003	Silvopastoral		0.090	0.0003	
45	Scrub	0.3	0.000	Silvopastoral		0.090	0.0000	
45	Scrub	0.0	0.000	Silvopastoral		0.090	0.0000	
45	Coffe	109.8	0.174	Silvopastoral		0.045	0.0078	
45	Coffe	11.8	0.019	Silvopastoral		0.045	0.0008	0.0781
46	Crop	1.1	0.000	Agroforestry		0.400	0.0001	
46	Crop	8.0	0.002	Agroforestry	Coffee (2nd)	0.039	0.0001	
46	Crop	14.0	0.003	Agroforestry	Coffee (2nd)	0.039	0.0001	
46	Crop	3.9	0.001	Agroforestry	Coffee (2nd)	0.039	0.0000	
46	Crop	12.1	0.003	Agroforestry	Coffee (2nd)	0.039	0.0001	
46	Crop	0.0	0.000	Agroforestry		0.400	0.0000	
46	Crop	0.5	0.000	Agroforestry		0.400	0.0000	
46	Crop	3.1	0.001	Agroforestry	Coffee (2nd)	0.039	0.0000	
46	Crop	16.0	0.004	Agroforestry	Coffee (2nd)	0.039	0.0001	
46	Crop	0.4	0.000	Agroforestry		0.400	0.0000	
46	Crop	33.2	0.007	Agroforestry	Coffee (2nd)	0.039	0.0003	
46	Crop	0.0	0.000	Agroforestry		0.400	0.0000	
46	Crop	40.5	0.009	Agroforestry	Coffee (2nd)	0.039	0.0003	
46	Crop	0.1	0.000	Agroforestry		0.400	0.0000	
46	Crop	57.5	0.013	Agroforestry	Coffee (2nd)	0.039	0.0005	
46	Crop	0.1	0.000	Agroforestry		0.400	0.0000	
46	Crop	50.0	0.011	Agroforestry	Energetic (3rd)	0.009	0.0001	
46	Crop	9.5	0.002	Agroforestry	Coffee (5th)	0.039	0.0001	
46	Crop	75.0	0.017	Agroforestry	Forestry (5th)	0.003	0.0000	
46	Crop	0.6	0.000	Agroforestry		0.400	0.0001	
46	Crop	28.4	0.006	Agroforestry	Coffee (5th)	0.039	0.0002	
46	Crop	8.3	0.002	Agroforestry	Coffee (5th)	0.039	0.0001	
46	Crop	50.0	0.011	Agroforestry	Energetic (1st)	0.009	0.0001	
46	Crop	82.6	0.018	Agroforestry	Coffee (2nd)	0.039	0.0007	
46	Crop	15.0	0.003	Agroforestry	Coffee (2nd)	0.039	0.0001	
46	Crop	8.8	0.002	Agroforestry	Coffee (2nd)	0.039	0.0001	
46	Crop	5.1	0.001	Agroforestry	Coffee (2nd)	0.039	0.0000	
46	Pasture	3.2	0.001	Agroforestry		0.042	0.0000	
46	Forest	1.3	0.000	Agroforestry		0.003	0.0000	
46	Forest	0.1	0.000	Agroforestry		0.003	0.0000	
46	Forest	0.6	0.000	Agroforestry		0.003	0.0000	
46	Forest	0.3	0.000	Agroforestry		0.003	0.0000	
46	Forest	59.3	0.013	Agroforestry		0.003	0.0000	
46	Coffe	0.5	0.000	Agroforestry		0.045	0.0000	
46	Coffe	4.0	0.001	Agroforestry		0.045	0.0000	
46	Coffe	11.0	0.002	Agroforestry		0.045	0.0001	
46	Coffe	12.4	0.003	Agroforestry		0.045	0.0001	
46	Coffe	10.1	0.002	Agroforestry		0.045	0.0001	

Table A-9 (Continued). Computed C Values for Jiguey Sub-basin "With" Project (5 years)

Micro-basin		Land use		Potential		C	Individual	Weighted
ID#	Type	(ha)	%	Land use	Type(yr)	Factor	C Values	C Values
46	Coffe	20.0	0.004	Agroforestry		0.045	0.0002	
46	Coffe	25.8	0.006	Agroforestry		0.045	0.0003	
46	Coffe	1.6	0.000	Agroforestry		0.045	0.0000	
46	Coffe	9.1	0.002	Agroforestry		0.045	0.0001	
46	Coffe	5.7	0.001	Agroforestry		0.045	0.0001	
46	Crop	103.8	0.023	Agroforestry	Coffee (5th)	0.039	0.0009	
46	Crop	50.0	0.011	Agroforestry	Energetic (5th)	0.009	0.0001	
46	Crop	100.0	0.022	Agroforestry	Forestry (4th)	0.003	0.0001	
46	Crop	434.6	0.096	Agroforestry		0.400	0.0383	
46	Crop	175.0	0.039	Agroforestry	Coffee (3rd)	0.039	0.0015	
46	Crop	100.0	0.022	Agroforestry	Forestry (1st)	0.003	0.0001	
46	Crop	75.0	0.017	Agroforestry	Forestry (3rd)	0.003	0.0000	
46	Crop	150.0	0.033	Agroforestry	Coffee (1st)	0.039	0.0013	
46	Crop	952.1	0.210	Agroforestry		0.400	0.0840	
46	Crop	250.0	0.055	Agroforestry	Coffee (4th)	0.039	0.0022	
46	Crop	125.0	0.028	Agroforestry	Forestry (2nd)	0.003	0.0001	
46	Scrub	32.2	0.007	Agroforestry		0.090	0.0006	
46	Pasture	8.5	0.002	Agroforestry		0.042	0.0001	
46	Pasture	29.8	0.007	Agroforestry		0.042	0.0003	
46	Pasture	59.6	0.013	Agroforestry		0.042	0.0006	
46	Pasture	96.8	0.021	Agroforestry		0.042	0.0009	
46	Forest	16.6	0.004	Agroforestry		0.003	0.0000	
46	Forest	21.6	0.005	Agroforestry		0.003	0.0000	
46	Forest	61.9	0.014	Agroforestry		0.003	0.0000	
46	Forest	26.6	0.006	Agroforestry		0.003	0.0000	
46	Forest	12.7	0.003	Agroforestry		0.003	0.0000	
46	Forest	15.5	0.003	Agroforestry		0.003	0.0000	
46	Forest	187.0	0.041	Agroforestry		0.003	0.0001	
46	Forest	1.0	0.000	Agroforestry		0.003	0.0000	
46	Forest	43.0	0.009	Agroforestry		0.003	0.0000	
46	Coffe	20.0	0.004	Agroforestry		0.045	0.0002	
46	Coffe	29.1	0.006	Agroforestry		0.045	0.0003	
46	Coffe	1.7	0.000	Agroforestry		0.045	0.0000	
46	Coffe	74.3	0.016	Agroforestry		0.045	0.0007	
46	Coffe	0.0	0.000	Agroforestry		0.045	0.0000	
46	Coffe	1.0	0.000	Agroforestry		0.045	0.0000	
46	Coffe	1.9	0.000	Agroforestry		0.045	0.0000	
46	Coffe	0.1	0.000	Agroforestry		0.045	0.0000	
46	Coffe	11.4	0.003	Agroforestry		0.045	0.0001	
46	Coffe	16.0	0.004	Agroforestry		0.045	0.0002	
46	Coffe	12.7	0.003	Agroforestry		0.045	0.0001	
46	Coffe	16.8	0.004	Agroforestry		0.045	0.0002	
46	Coffe	17.8	0.004	Agroforestry		0.045	0.0002	
46	Coffe	105.4	0.023	Agroforestry		0.045	0.0010	
46	Coffe	91.5	0.020	Protection		0.045	0.0009	
46	Scrub	5.1	0.001	Silvopastoral		0.090	0.0001	
46	Pasture	11.5	0.003	Silvopastoral		0.042	0.0001	
46	Pasture	19.5	0.004	Silvopastoral		0.042	0.0002	
46	Coffe	262.1	0.058	Silvopastoral		0.045	0.0026	
46	Coffe	18.9	0.004	Silvopastoral		0.045	0.0002	0.1429

Table A-10. C Values for Jiguey Sub-basin "With" Project (5 years)

Micro-basin ID#	Type	Land use (ha)	%	Potential Land use	Proposed Land use (yr)	C Factor	Individual C Values	Weighted C Values
51	Coffe	33.3	0.115	Forestry		0.045	0.0052	
51	Coffe	256.1	0.885	Forestry		0.045	0.0398	0.045
52	Coffe	291.0	1.000	Protection		0.045	0.0450	0.045
53	Coffe	662.3	0.512	Forestry		0.045	0.0230	
53	Coffe	630.3	0.488	Agroforestry		0.045	0.0220	0.045
54	Coffe	136.2	0.366	Agroforestry		0.045	0.0165	
54	Coffe	1.6	0.004	Agroforestry		0.045	0.0002	
54	Crop	50.0	0.134	Protection		0.400	0.0537	
54	Crop	75.0	0.201	Protection	Forestry (2nd)	0.003	0.0006	
54	Crop	50.0	0.134	Protection	Forestry (2nd)	0.003	0.0004	
54	Crop	35.2	0.095	Protection	Forestry (3rd)	0.003	0.0003	
54	Pasture	4.9	0.013	Protection		0.042	0.0006	
54	Coffe	4.1	0.011	Protection		0.045	0.0005	
54	Coffe	0.2	0.001	Protection		0.045	0.0000	
54	Coffe	0.3	0.001	Agroforestry		0.045	0.0000	
54	Pasture	14.8	0.040	Agroforestry	Forestry (3rd)	0.003	0.0001	0.073
55	Coffe	0.0	0.000	Forestry		0.045	0.0000	
55	Coffe	0.6	0.000	Protection		0.045	0.0000	
55	Pasture	0.0	0.000	Agroforestry		0.042	0.0000	
55	Crop	3.2	0.001	Agroforestry		0.400	0.0006	
55	Crop	0.2	0.000	Protection		0.400	0.0000	
55	Crop	200.0	0.093	Agroforestry	Coffee (2nd)	0.039	0.0036	
55	Crop	55.0	0.026	Protection	Energetic (1st)	0.009	0.0002	
55	Crop	125.0	0.058	Agroforestry	Coffee (1st)	0.039	0.0023	
55	Crop	100.0	0.047	Agroforestry	Coffee (3rd)	0.039	0.0018	
55	Crop	65.0	0.030	Agroforestry	Coffee (4th)	0.039	0.0012	
55	Coffe	0.2	0.000	Agroforestry		0.045	0.0000	
55	Crop	5.0	0.002	Protection		0.400	0.0009	
55	Coffe	15.8	0.007	Agroforestry		0.045	0.0003	
55	Coffe	0.0	0.000	Agroforestry		0.045	0.0000	
55	Pasture	32.1	0.015	Agroforestry		0.042	0.0006	
55	Coffe	693.4	0.324	Agroforestry		0.045	0.0146	
55	Coffe	99.2	0.046	Agroforestry		0.045	0.0021	
55	Scrub	100.0	0.047	Agroforestry		0.090	0.0042	
55	Scrub	160.3	0.075	Protection		0.090	0.0067	
55	Crop	75.0	0.035	Protection	Forest (4th)	0.003	0.0001	
55	Crop	11.0	0.005	Protection		0.400	0.0021	
55	Crop	2.1	0.001	Protection		0.400	0.0004	
55	Coffe	5.9	0.003	Protection		0.045	0.0001	
55	Crop	43.9	0.021	Protection		0.400	0.0082	
55	Coffe	0.5	0.000	Protection		0.045	0.0000	
55	Coffe	23.7	0.011	Agroforestry		0.045	0.0005	
55	Pasture	6.2	0.003	Protection		0.042	0.0001	
55	Coffe	14.4	0.007	Forestry		0.045	0.0003	
55	Coffe	19.8	0.009	Protection		0.045	0.0004	
55	Pasture	75.6	0.035	Protection		0.042	0.0015	
55	Coffee	0.1	0.000	Protection		0.045	0.0000	
55	Pasture	6.4	0.003	Protection		0.042	0.0001	
55	Crop	50.0	0.023	Agroforestry	Forestry (1st)	0.003	0.0001	
55	Crop	75.0	0.035	Protection	Forestry (3rd)	0.003	0.0001	

Table A-10 (Continued). C Values for Jiguey Sub-basin "With" Project (5 years)

Micro-basin		Land use		Potential	Proposed	C	Individual	Weighted
ID#	Type	(ha)	%	Land use	Land use (yr)	Factor	C Values	C Values
55	Scrub	1.6	0.001	Protection		0.090	0.0001	
55	Crop	55.0	0.026	Protection	Energetic (3rd)	0.009	0.0002	
55	Crop	2.8	0.001	Agroforestry		0.400	0.0005	
55	Pasture	15.9	0.007	Agroforestry		0.042	0.0003	0.054
56	Crop	21.0	0.010	Protection		0.400	0.0039	
56	Crop	50.0	0.023	Agroforestry	Forestry (3rd)	0.003	0.0001	
56	Crop	50.0	0.023	Agroforestry	Forestry (2nd)	0.003	0.0001	
56	Crop	24.7	0.012	Agroforestry		0.400	0.0046	
56	Coffee	645.8	0.302	Agroforestry		0.045	0.0136	
56	Crop	9.0	0.004	Agroforestry		0.400	0.0017	
56	Pasture	485.3	0.227	Agroforestry		0.042	0.0095	
56	Crop	5.3	0.002	Agroforestry		0.400	0.0010	
56	Ext. Cro	55.0	0.026	Agroforestry	Energetic (4th)	0.009	0.0002	
56	Ext. Cro	100.0	0.047	Agroforestry	Coffee (5th)	0.039	0.0018	
56	Ext. Cro	547.9	0.256	Agroforestry		0.120	0.0307	
56	Crop	50.0	0.023	Agroforestry	Forestry (4th)	0.003	0.0001	
56	Coffee	38.3	0.018	Agroforestry		0.045	0.0008	
56	Coffee	56.6	0.026	Agroforestry		0.045	0.0012	0.069
57	Coffee	565.7	0.263	Agroforestry		0.045	0.0118	
57	Coffee	18.4	0.009	Agroforestry		0.045	0.0004	
57	Pasture	6.1	0.003	Protection		0.042	0.0001	
57	Pasture	55.0	0.026	Agroforestry	Energetic (2nd)	0.009	0.0002	
57	Crop	50.0	0.023	Agroforestry	Forestry (4th)	0.003	0.0001	
57	Crop	100.0	0.047	Agroforestry	Forestry (5th)	0.003	0.0001	
57	Crop	75.0	0.035	Agroforestry	Forestry (2nd)	0.009	0.0003	
57	Scrub	30.6	0.014	Protection		0.090	0.0013	
57	Crop	55.0	0.026	Protection	Energetic (5th)	0.009	0.0002	
57	Crop	135.0	0.063	Protection	Coffee (4th)	0.039	0.0025	
57	Pasture	4.1	0.002	Protection		0.042	0.0001	
57	Pasture	394.7	0.184	Protection		0.042	0.0077	
57	Coffee	4.2	0.002	Protection		0.045	0.0001	
57	Pasture	0.1	0.000	Protection		0.042	0.0000	
57	Coffee	263.3	0.123	Protection		0.045	0.0055	
57	Pasture	2.1	0.001	Agroforestry		0.042	0.0000	
57	Crop	41.5	0.019	Agroforestry		0.400	0.0077	
57	Crop	100.0	0.047	Agroforestry	Coffee (3rd)	0.039	0.0018	
57	Coffee	1.7	0.001	Agroforestry		0.045	0.0000	
57	Crop	27.2	0.013	Protection		0.400	0.0051	
57	Crop	15.8	0.007	Agroforestry		0.400	0.0029	
57	Pasture	12.7	0.006	Agroforestry		0.042	0.0002	
57	Coffee	19.6	0.009	Agroforestry		0.045	0.0004	
57	Pasture	171.2	0.080	Protection		0.042	0.0033	0.052
58	Coffee	155.7	0.055	Protection		0.045	0.0025	
58	Coffee	819.8	0.292	Protection		0.045	0.0131	
58	Pasture	171.4	0.061	Protection		0.042	0.0026	
58	Pasture	636.6	0.227	Protection		0.042	0.0095	
58	Coffee	108.1	0.039	Protection		0.045	0.0017	
58	Coffee	11.1	0.004	Protection		0.045	0.0002	
58	Forest	907.0	0.323	Protection		0.003	0.0010	0.031

Table A-11. Sedimentation rates and Sediments Delivered by Sub-basin for Aguacate Basin

Year	Year of Dam	Year of Project	Sedimentation Rate						Delivered Sediments
			Mahomita		Jiguey		Total		
			Ton/ha	Ton/year	Ton/ha	Ton/year	Ton/year	m3/year	m3/year
1993	1		15.734	180,657.8	28.952	284,598.2	465,255.9	387,713.3	302,416.4
1994	2		15.734	180,657.8	28.952	284,598.2	465,255.9	387,713.3	302,416.4
1995	3		15.734	180,657.8	28.952	284,598.2	465,255.9	387,713.3	302,416.4
1996	4	1	15.734	180,657.8	28.952	284,598.2	465,255.9	387,713.3	302,416.4
1997	5	2	15.734	180,657.8	28.952	284,598.2	465,255.9	387,713.3	302,416.4
1998	6	3	15.734	180,657.8	28.952	284,598.2	465,255.9	387,713.3	302,416.4
1999	7	4	10.831	124,361.5	22.108	217,321.6	341,683.2	284,736.0	222,094.1
2000	8	5	7.832	89,927.0	18.787	184,676.2	274,603.2	228,836.0	178,492.1
2001	9	6	5.205	59,763.8	16.815	165,291.5	225,055.3	187,546.1	146,285.9
2002	10	7	3.946	45,308.0	12.522	123,091.3	168,399.2	140,332.7	109,459.5
2003	11	8	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2004	12	9	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2005	13	10	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2006	14	11	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2007	15	12	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2008	16	13	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2009	17	14	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2010	18	15	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2011	19	16	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2012	20	17	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2013	21	18	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2014	22	19	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2015	23	20	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2016	24	21	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2017	25	22	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2018	26	23	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2019	27	24	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3
2020-45	28-53	25-50	3.571	41,002.2	11.137	109,476.7	150,478.9	125,399.1	97,811.3

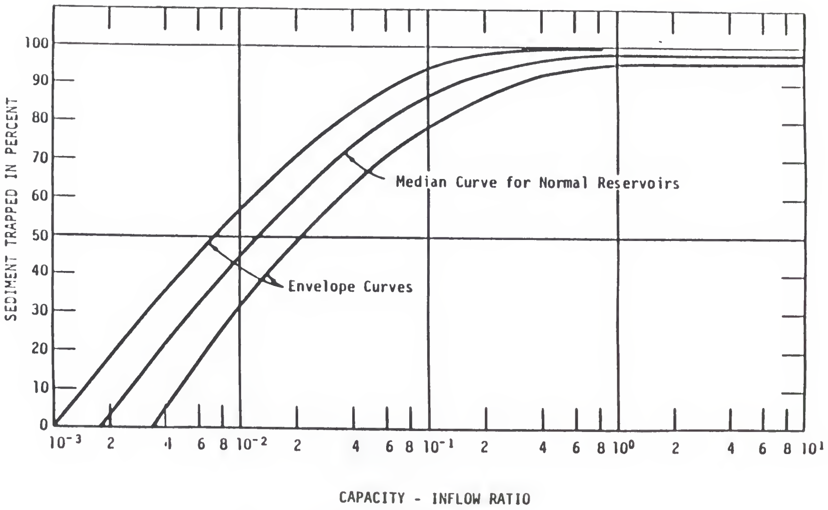


Figure A-2. Brune's Curve for Reservoir Trap Efficiency (Mahmood, 1989)

Table A-12. Accumulated Sediments by the Reservoir Storage "Without" Spillway

		"Wittout" Project		"With" Project	
Year	Year of Dam	Delivered Sediments	Accumulated Sediments	Delivered Sediments	Accumulated Sediments
		............................Sediments in Cubic Meters...................................			
1993	1	302,416.4	302,416.4	302,416.4	302,416.4
1994	2	302,416.4	604,832.7	302,416.4	604,832.7
1995	3	302,416.4	907,249.1	302,416.4	907,249.1
1996	4	302,416.4	1,209,665.5	302,416.4	1,209,665.4
1997	5	302,416.4	1,512,081.9	302,416.4	1,512,081.8
1998	6	302,416.4	1,814,498.2	302,416.4	1,814,498.2
1999	7	302,416.4	2,116,914.6	222,094.1	2,036,592.2
2000	8	302,416.4	2,419,331.0	178,492.1	2,215,084.3
2001	9	302,416.4	2,721,747.3	146,285.9	2,361,370.3
2002	10	302,416.4	3,024,163.7	109,459.5	2,470,829.8
2003	11	302,416.4	3,326,580.1	97,811.3	2,568,641.1
2004	12	302,416.4	3,628,996.4	97,811.3	2,666,452.4
2005	13	302,416.4	3,931,412.8	97,811.3	2,764,263.7
2006	14	302,416.4	4,233,829.2	97,811.3	2,862,075.0
2007	15	302,416.4	4,536,245.5	97,811.3	2,959,886.3
2008	16	302,416.4	4,838,661.9	97,811.3	3,057,697.6
2009	17	302,416.4	5,141,078.3	97,811.3	3,155,508.9
2010	18	302,416.4	5,443,494.6	97,811.3	3,253,320.2
2011	19	302,416.4	5,745,911.0	97,811.3	3,351,131.5
2012	20	302,416.4	6,048,327.4	97,811.3	3,448,942.8
2013	21	302,416.4	6,350,743.7	97,811.3	3,546,754.1
2014	22	302,416.4	6,653,160.1	97,811.3	3,644,565.4
2015	23	302,416.4	6,955,576.5	97,811.3	3,742,376.7
2016	24	302,416.4	7,257,992.8	97,811.3	3,840,188.0
2017	25	302,416.4	7,560,409.2	97,811.3	3,937,999.3
2018	26	302,416.4	7,862,825.6	97,811.3	4,035,810.6
2019	27	302,416.4	8,165,241.9	97,811.3	4,133,622.0
2020	28	302,416.4	8,467,658.3	97,811.3	4,231,433.3
2021	29	302,416.4	8,770,074.7	97,811.3	4,169,244.6
2022	30	302,416.4	9,072,491.0	97,811.3	4,267,055.9
2023	31	302,416.4	9,374,907.4	97,811.3	4,204,867.2
2024	32	302,416.4	9,677,323.8	97,811.3	4,302,678.5
2025	33	302,416.4	9,979,740.1	97,811.3	4,400,489.8
2026	34	302,416.4	10,282,156.5	97,811.3	4,338,301.1
2027	35	302,416.4	10,584,572.9	97,811.3	4,436,112.4
2028	36	302,416.4	10,886,989.2	97,811.3	4,533,923.7
2029	37	302,416.4	11,189,405.6	97,811.3	4,471,735.0
2030	38	302,416.4	11,491,821.9	97,811.3	4,569,546.3
2031	39	302,416.4	11,794,238.3	97,811.3	4,667,357.6
2032	40	302,416.4	12,096,654.7	97,811.3	4,605,168.9
2033	41	302,416.4	12,399,071.0	97,811.3	4,702,980.2
2034	42	302,416.4	12,701,487.4	97,811.3	4,640,791.5
2035	43	302,416.4	13,003,903.8	97,811.3	4,738,602.8
2040	48	302,416.4	14,515,985.6	97,811.3	4,907,659.4
2045	53	302,416.4	16,028,067.5	97,811.3	5,396,715.9

Table A-13. Sediments Drawn by the Spillway Gates and Reservoir Lifetime "Without" Project

Year	Year of Dam	Accumulated Sediments	CASE I 300,000 (100%)	CASE II 270,000 (90%)	CASE III 240,000 (80%)	CASE IV 210,000 (70%)	CASE V 180,000 (60%)	CASE VI 150,000 (50%)	CASE VII 120,000 (40%)	CASE VIII 90,000 (30%)	CASE IX 60,000 (20%)	CASE X 30,000 (10%)
		....Sediments in Cubic Meters....										
1993	1	302416										
1994	2	604833										
1995	3	907249										
1996	4	1209665										
1997	5	1512082										
1998	6	1814498										
1999	7	2116915	1816915	1846915	1876915	1906915	1936915	1966915	1996915	2026915	2056915	2086915
2000	8	2419331	1819331	1879331	1939331	1999331	2059331	2119331	2179331	2239331	2299331	2359331
2001	9	2721747	1821747	1911747	2001747	2091747	2181747	2271747	2361747	2451747	2541747	2631747
2002	10	3024164	1824164	1944164	2064164	2184164	2304164	2424164	2544164	2664164	2784164	2904164
2003	11	3326580	1826580	1976580	2126580	2276580	2426580	2576580	2726580	2876580	3026580	3176580
2004	12	3628996	1828996	2008996	2188996	2368996	2548996	2728996	2908996	3088996	3268996	3448996
2005	13	3931413	1831413	2041413	2251413	2461413	2671413	2881413	3091413	3301413	3511413	3721413
2006	14	4233829	1833829	2073829	2313829	2553829	2793829	3033829	3273829	3513829	3753829	3993829
2007	15	4536245	1836245	2106245	2376245	2646245	2916245	3186245	3456245	3726245	3996245	4266245
2008	16	4838662	1838662	2138662	2438662	2738662	3038662	3338662	3638662	3938662	4238662	4538662
2009	17	5141078	1841078	2171078	2501078	2831078	3161078	3491078	3821078	4151078	4481078	4811078
2010	18	5443495	1843495	2203495	2563495	2923495	3283495	3643495	4003495	4363495	4723495	5083495
2011	19	5745911	1845911	2235911	2625911	3015911	3405911	3795911	4185911	4575911	4965911	5355911
2012	20	6048327	1848327	2268327	2688327	3108327	3528327	3948327	4368327	4788327	5208327	5628327
2013	21	6350744	1850744	2300744	2750744	3200744	3650744	4100744	4550744	5000744	5450744	5900744
2014	22	6653160	1853160	2333160	2813160	3293160	3773160	4253160	4733160	5213160	5693160	6173160
2015	23	6955576	1855576	2365576	2875576	3385576	3895576	4405576	4915576	5425576	5935576	6445576
2020	28	8467658	1867658	2527658	3187658	3847658	4507658	5167658	5827658	6487658	7147658	7807658
2025	33	9979740	1879740	2689740	3499740	4309740	5119740	5929740	6739740	7549740	8359740	9169740
2029	37	11189406	1889406	2819406	3749406	4679406	5609406	6539406	7469406	8399406	9329406	10259406
2030	38	11491822	1891822	2851822	3811822	4771822	5731822	6691822	7651822	8611822	9571822	10531822

Table A-14. Sediments Drawn by the Spillway Gates and Reservoir Lifetime "With" Project

Year	Year of Dam	Accumulated Sediments	CASE I 300,000 (100%)	CASE II 270,000 (90%)	CASE III 240,000 (80%)	CASE IV 210,000 (70%)	CASE V 180,000 (60%)	CASE VI 150,000 (50%)	CASE VII 120,000 (40%)	CASE VIII 90,000 (30%)	CASE IX 60,000 (20%)	CASE X 30,000 (10%)
		……………………………………………………Sediments in Cubic Meters……………………………………										
1993	1											
1994	2	604833										
1995	3	907249										
1996	4	1209665										
1997	5	1512082										
1998	6	1814498										
1999	7	2036592										
2000	8	2215084	1915084	1945084	1975084	2005084	2035084	2065084	2095084	2125084	2155084	2185084
2001	9	2361370	1761370	1821370	1881370	1941370	2001370	2061370	2121370	2181370	2241370	2331370
2002	10	2470830	1570830	1660830	1750830	1840830	1930830	2020830	2110830	2200830	2290830	2440830
2003	11	2568641	1368641	1488641	1608641	1728641	1848641	1968641	2088641	2208641	2328641	2538641
2004	12	2666452	1166452	1316452	1466452	1616452	1766452	1916452	2066452	2216452	2366452	2636452
2005	13	2764264	964264	1144264	1324264	1504264	1684264	1864264	2044264	2224264	2404264	2734264
2006	14	2862075	762075	972075	1182075	1392075	1602075	1812075	2022075	2232075	2442075	2832075
2007	15	2959886	559886	799886	1039886	1279886	1519886	1759886	1999886	2239886	2479886	2929886
2008	16	3057698	357698	627698	897698	1167698	1437698	1707698	1977698	2247698	2517698	3027698
2009	17	3155509	155509	455509	755509	1055509	1355509	1655509	1955509	2255509	2555509	3125509
2010	18	3253320		283320	613320	943320	1273320	1603320	1933320	2263320	2593320	3223320
2011	19	3351132		111132	471132	831132	1191132	1551132	1911132	2271132	2631132	3321132
2012	20	3448943			328943	718943	1108943	1498943	1888943	2278943	2668943	3418943
2013	21	3546754			186754	606754	1026754	1446754	1866754	2286754	2706754	3516754
2014	22	3644565			44565	494565	944565	1394565	1844565	2294565	2744565	3614565
2015	23	3742377				382377	862377	1342377	1822377	2302377	2782377	3712377
2016	24	3840188				270188	780188	1290188	1800188	2310188	2820188	3810188
2017	25	3937999				157999	697999	1237999	1777999	2317999	2857999	3907999
2018	26	4035811				45811	615811	1185811	1755811	2325811	2895811	4005811
2019	27	4133622					533622	1133622	1733622	2333622	2933622	4103622
2020	28	4231433					451433	1081433	1711433	2341433	2971433	4201433

Table A-15. Economic Value of the Sediments Avoided "With" Project

Year	Year of Dam	Delivered Sediments		Avoided Sediments	Economic Value*
		"Without" Project	"With Project"		
		........................Cubic Meters	....		(DR$)
1996	4	302,416.4	302,416.4	0.0	0.0
1997	5	302,416.4	302,416.4	0.0	0.0
1998	6	302,416.4	302,416.4	0.0	0.0
1999	7	302,416.4	222,094.1	80,322.3	6,812,134.3
2000	8	302,416.4	178,492.1	123,924.3	10,510,019.9
2001	9	302,416.4	146,285.9	156,130.5	13,241,427.7
2002	10	302,416.4	109,459.5	192,956.9	16,364,674.7
2003	11	302,416.4	97,811.3	204,605.1	17,352,558.5
2004	12	302,416.4	97,811.3	204,605.1	17,352,558.5
2005	13	302,416.4	97,811.3	204,605.1	17,352,558.5
2006	14	302,416.4	97,811.3	204,605.1	17,352,558.5
2007	15	302,416.4	97,811.3	204,605.1	17,352,558.5
2008	16	302,416.4	97,811.3	204,605.1	17,352,558.5
2009	17	302,416.4	97,811.3	204,605.1	17,352,558.5
2010	18	302,416.4	97,811.3	204,605.1	17,352,558.5
2011	19	302,416.4	97,811.3	204,605.1	17,352,558.5
2012	20	302,416.4	97,811.3	204,605.1	17,352,558.5
2013	21	302,416.4	97,811.3	204,605.1	17,352,558.5
2014	22	302,416.4	97,811.3	204,605.1	17,352,558.5
2015	23	302,416.4	97,811.3	204,605.1	17,352,558.5
2016	24	302,416.4	97,811.3	204,605.1	17,352,558.5
2017	25	302,416.4	97,811.3	204,605.1	17,352,558.5
2018	26	302,416.4	97,811.3	204,605.1	17,352,558.5
2019	27	302,416.4	97,811.3	204,605.1	17,352,558.5
2020	28	302,416.4	97,811.3	204,605.1	17,352,558.5
2021	29	302,416.4	97,811.3	204,605.1	17,352,558.5
2022	30	302,416.4	97,811.3	204,605.1	17,352,558.5
2023	31	302,416.4	97,811.3	204,605.1	17,352,558.5
2024	32	302,416.4	97,811.3	204,605.1	17,352,558.5
2025	33	302,416.4	97,811.3	204,605.1	17,352,558.5
2026	34	302,416.4	97,811.3	204,605.1	17,352,558.5
2027	35	302,416.4	97,811.3	204,605.1	17,352,558.5
2028	36	302,416.4	97,811.3	204,605.1	17,352,558.5
2029	37	302,416.4	97,811.3	204,605.1	17,352,558.5
2030	38	302,416.4	97,811.3	204,605.1	17,352,558.5
2031	39	302,416.4	97,811.3	204,605.1	17,352,558.5
2032	40	302,416.4	97,811.3	204,605.1	17,352,558.5
2033	41	302,416.4	97,811.3	204,605.1	17,352,558.5
2034	42	302,416.4	97,811.3	204,605.1	17,352,558.5
2035	43	302,416.4	97,811.3	204,605.1	17,352,558.5
2036	44	302,416.4	97,811.3	204,605.1	17,352,558.5
2037	45	302,416.4	97,811.3	204,605.1	17,352,558.5
2038	46	302,416.4	97,811.3	204,605.1	17,352,558.5
2039	47	302,416.4	97,811.3	204,605.1	17,352,558.5
2040-45	48-53	302,416.4	97,811.3	204,605.1	17,352,558.5

* 1 m3 of storage capacity = DR$84.81

Table A-16. Summary of Economic Analysis of 1 ha of Coffee System

Year	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40-50
Costs (DR$)																
Non-labor Costs	10676	6085	4050	12695	7235	7285	7310	8060	7210	7210	7210	5358	7210	7210	5718	7210
Labor Costs*																
Pre-harvest	7238	4013	2738	325	2400	2513	2588	2475	2475	2475	2475	1463	2475	2475	1538	2475
Harvest	825	1200	819	2000	4000	5600	5600	5600	5825	5600	5600	3600	5600	5600	2800	5600
Labor Cost	8063	5213	3556	5225	6400	8113	8188	8075	8300	8075	8075	5063	8075	8075	4338	8075
Workers' Food	3019	1344	619	775	675	713	738	800	875	800	800	638	800	800	663	800
Conservation																
Non-labor Costs	1120															
Labor Cost	975							300	300	300	300	450	300	300	450	300
Total Costs	23853	12642	8226	15795	14310	16111	16236	17235	16685	16385	16385	11509	16385	16385	11169	16385
Revenues (DR$)																
Coffee			3200	8000	16000	22400	22400	22400	22400	22400	22400	14400	22400	22400	11200	22400
Palmhearts trees									336							
Banana		4000	250													
Cassava	2600	2600														
Kidney bean	8000	8000														
Corn	540	540														
Squash		2000														
Total Income	11140	17140	3450	8000	16000	22400	22400	22400	22736	22400	22400	14400	22400	22400	11200	22400

*50% of labor is contracted at DR$50.00, the other 50% is family labor

Source: IFAD (1993)

Table A-17. Summary Economic Analysis of 1 ha of Energitic Trees

Year	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	45	50
Costs (DR$)																		
Non-labor Costs																		
Plants (units)	2500	250																
Non-labor Costs	3750	375																
Labor Costs																		
Planting (man-day)	47	5																
Management (man-day)		20	28	8	8	8	8	8	8									
Harvest (man-day)								11	11	11	8	8	8	8	8	10	10	10
Total Labor (man-day)	47	25	28	8	8	8	8	19	19	11	8	8	8	8	8	10	10	10
Labor Cost ($50/day)	2350	1250	1400	400	400	400	400	950	950	550	400	400	375	375	375	500	500	500
Total Costs	6100	1625	1400	400	400	400	400	950	950	550	400	400	375	375	375	500	500	500
Revenues (DR$)																		
Production (m3)								3	3	3	3	3	3	3	3	3	3	3
Total Income ($400/m3)								1120	1120	1120	1120	1120	1120	1120	1120	1120	1120	1120

Source: IFAD (1993)

Table A-18. Summary of the Costs of 1 ha of Forest

Year	1	2	3	4	5	6	7	8	9	10	15	20	25	30	35	40	45	50
Costs (DR$)																		
Non-labor Costs																		
Plants (units)	2200	250																
Non-labor Costs	2580	375																
Labor Costs																		
Land Preparation	400																	
Site Preparation	500																	
Planting	350	250																
Mangement	1150	1050	450	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Labor Cost ($50/day)	2400	1300	450	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total Costs	4980	1675	450	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50

Source: IFAD (1993)

Table A-19. Estimated Cost (DR$) for the Proposed Watershed Management Project

PROGRAM	YEAR					TOTAL
	1	2	3	4	5	
Extension	620,000	620,000	620,000	520,000	520,000	2,900,000
Conservation	1,400,000	1,400,000	1,140,000	1,140,000	960,000	6,040,000
Engineering	2,600,000	2,200,000	2,200,000	1,900,000	1,900,000	10,800,000
Studies	1,200,000	840,000	760,000	400,000	400,000	3,600,000
Land Acquisition	1,280,000	1,280,000	1,280,000	1,280,000	1,280,000	6,400,000
Training	280,000	280,000	280,000	160,000	120,000	1,120,000
External Assistance	560,000	560,000	560,000	560,000	560,000	2,800,000
Administration	680,000	680,000	680,000	680,000	680,000	3,400,000
Total Costs	8,620,000	7,860,000	7,520,000	6,640,000	6,420,000	37,060,000

Source: Amaya (1993)

Table A-20. Expected Net Present Values Per Year

Year	Project	Discount Rate					
	Year	8%	10%	12%	14%	16%	18%
1996	1	(14,691,031)	(14,423,922)	(14,166,352)	(13,917,819)	(13,677,857)	(13,446,029)
1997	2	(15,139,386)	(14,593,867)	(14,077,311)	(13,587,703)	(13,123,201)	(12,682,117)
1998	3	(14,322,260)	(13,555,164)	(12,841,884)	(12,177,784)	(11,558,696)	(10,980,871)
1999	4	(10,657,600)	(9,903,386)	(9,214,724)	(8,584,896)	(8,007,971)	(7,478,705)
2000	5	(6,008,939)	(5,482,178)	(5,009,870)	(4,585,559)	(4,203,651)	(3,859,282)
2001	6	2,839,242	2,543,249	2,282,637	2,052,655	1,849,256	1,668,987
2002	7	6,523,691	5,737,344	5,057,473	4,468,129	3,955,977	3,509,827
2003	8	10,278,537	8,875,235	7,683,819	6,669,335	5,803,065	5,061,337
2004	9	12,059,678	10,223,870	8,693,353	7,413,202	6,339,100	5,435,149
2005	10	11,622,198	9,673,842	8,078,777	6,768,264	5,687,821	4,794,085
2006	11	10,670,644	8,720,320	7,152,431	5,887,062	4,861,990	4,028,560
2007	12	9,907,526	7,949,468	6,403,745	5,178,358	4,202,952	3,423,467
2008	13	9,186,958	7,237,285	5,725,933	4,549,016	3,628,497	2,905,457
2009	14	8,471,562	6,552,371	5,091,477	3,974,003	3,115,188	2,452,155
2010	15	7,829,567	5,945,711	4,537,574	3,479,536	2,680,552	2,074,264
2011	16	7,235,838	5,394,932	4,043,715	3,046,431	2,306,434	1,754,514
2012	17	6,686,769	4,894,908	3,603,411	2,667,090	1,984,423	1,483,973
2013	18	6,179,019	4,440,980	3,210,870	2,334,854	1,707,274	1,255,079
2014	19	5,709,498	4,028,917	2,860,928	2,043,888	1,468,749	1,061,430
2015	20	5,105,407	3,537,136	2,466,863	1,731,444	1,222,773	868,691
2016	21	4,587,253	3,120,364	2,137,338	1,473,838	1,022,901	714,380
2017	22	4,234,429	2,827,993	1,902,484	1,288,875	879,107	603,550
2018	23	3,908,463	2,562,835	1,693,315	1,127,044	755,472	509,878
2019	24	3,718,623	2,394,020	1,553,530	1,015,865	669,207	444,001
2020	25	3,535,629	2,234,825	1,424,328	915,038	592,394	386,376
2021	26	3,263,720	2,025,446	1,267,833	800,211	509,123	326,436
2022	27	3,012,502	1,835,550	1,128,450	699,742	437,525	275,775
2023	28	2,780,412	1,663,333	1,004,315	611,841	375,968	232,958
2024	29	2,566,006	1,507,158	893,766	534,941	323,046	196,774
2025	30	2,367,684	1,365,387	795,235	467,618	277,522	166,179
2026	31	2,184,511	1,236,851	707,509	408,734	238,393	140,329
2027	32	2,015,340	1,120,321	629,407	357,234	204,764	118,491
2028	33	1,859,108	1,014,682	559,878	312,197	175,863	100,042
2029	34	1,714,835	918,922	497,986	272,813	151,028	84,458
2030	35	1,475,912	776,512	413,296	222,445	121,021	66,531
2031	36	1,280,656	661,532	345,811	182,858	97,769	52,837
2032	37	1,180,265	598,590	307,321	159,654	83,891	44,568
2033	38	1,087,618	541,573	273,083	139,378	71,974	37,589
2034	39	1,072,753	524,459	259,731	130,238	66,094	33,933
2035	40	1,053,428	505,647	245,943	121,160	60,428	30,498
2036	41	970,439	457,343	218,476	105,741	51,828	25,715
2037	42	893,883	413,605	194,054	92,273	44,447	21,679
2038	43	823,267	374,005	172,341	80,511	38,113	18,274
2039	44	758,136	338,154	153,038	70,239	32,677	15,402
2040	45	698,479	305,880	135,960	61,306	28,029	12,988
2041	46	643,435	276,652	120,773	53,503	24,040	10,950
2042	47	592,652	250,184	107,268	46,686	20,615	9,231
2043	48	589,469	248,840	106,692	46,435	20,505	9,182
2044	49	586,221	247,470	106,104	46,180	20,392	9,131
2045	50	582,909	246,072	105,504	45,919	20,276	9,080
Total	NPV	115,524,955	70,391,254	41,043,629	21,300,019	7,657,087	(1,962,813)

Table A-21. Benefit-Cost Ratio by Discount Rate

Discount Rate	NPV Benefit	NPV Cost	B/C Ratio
8%	550,945,178.51	435,420,223.06	1.265
10%	417,553,503.15	347,162,249.09	1.203
12%	327,413,525.06	286,369,896.08	1.143
14%	263,775,336.18	242,475,317.09	1.088
16%	217,173,647.74	209,516,560.26	1.037
18%	181,997,809.13	183,960,622.32	0.989

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BIOGRAPHICAL SKETCH

Hector René Ledesma was born in Dominican Republic (DR), on June 7, 1951. He studied agronomy at the Instituto Politécnico Loyola (IPL) and graduated in 1971. He obtained the Agricultural Engineers' degree from the Universidad Nacional Pedro Henríquez Ureña (UNPHU) in 1974. A year later, he joined to the Soil and Water Department of the Secretariat of Agriculture (DR). In 1976, he received the certificate of specialization in Airphoto-interpretation from the Interamerican Photo-interpretation Center (CIAF) in Bogotá, Colombia. In 1978, he became Head of the Division of Soil Surveys of the Secretariat of Agriculture. In 1981, he enrolled as a graduate student in the Geography Department of the University of Florida, where he received the degree of Master of Science in the area of natural resources. In 1983, he returned to his native Dominican Republic as Head of the Planning Division of the Land and Water Department of the Secretariat of Agriculture. At the same time, he started to teach in the Agronomy Department of the Universidad Autónoma de Santo Domingo. Later, he also began to teach in the Natural Resources Department of the UNPHU, until 1991. In 1984, he was appointed as Director of the Natural Resources Inventory Department. In 1987, he started as a consultant in the natural resources area, at AGROHORTI Consulting Company (DR). In 1990, he became Project Manager of PRONATURA (DR), a Non-profit Organization dedicated to management projects in conservation and protection of the natural resources. In 1991, he returned to the University of Florida, where he has been pursuing a Ph.D. in geography with specialization in natural resources management and a minor in food resources economics.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Gustavo Antonini, Chair
Professor of Geography

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Peter Waylen, Cochair
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Joann Mossa
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Edward Malecki
Professor of Geography

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This dissertation was submitted to the Graduate Faculty of the Department of Geography in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

May, 1996

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